STATE OF OHIO
DEPARTMENT OF NATURAL RESOURCES
DIVISION OF GEOLOGICAL SURVEY
HORACE R. COLLINS, Chief

BULLETIN 66

# GEOLOGY AND MINERAL RESOURCES OF WASHINGTON COUNTY, OHIO

by

Horace R. Collins
and
Bradley E. Smith

COLUMBUS
1977

DEPARTMENT OF NATURAL RESOURCES

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Photocopy composer: Jean M. Lesher (Chapter 6 analyses – Donna M. Swartz)
Cartographers: James A. Brown and Donald R. Camburn

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# ABSTRACT

The exposed rock section in Washington County, Ohio, consists of an aggregate thickness of approximately 1,100 feet of interbedded mudstones, sandstones, siltstones, and lesser quantities of shale, coal, limestone, and clay. The surface rocks of the county range stratigraphically from the Pennsylvanian Conemaugh Group to the Permian Dunkard Group.

Wells drilled for oil and gas have penetrated rocks from the Permian-age Dunkard Group to the Queenston Formation of Ordovician age. The deepest well in the county reached Ordovician rocks (Queenston) after being drilled 7,889 feet from slightly above the Washington coal.

The rocks of Washington County have a complex geologic history; the interpretations offered in this report should be considered only tentative and subject to much revision following detailed regional studies. Although a large number of stratigraphic sections were analyzed for this report, the authors felt the coverage and quality of the section barely adequate. It is felt also that because of the complex sedimentary framework, of which Washington County is only a part, regional stratigraphic studies would be of much greater value in unraveling the detailed geologic history of the area.

For all systems for which there are data the rocks thicken from west to east across the county. The shortest rock sequences are uniformly found along the Athens-Washington County line, and the longest sequences are along the Ohio River in Grandview, Independence, and Newport Townships.

The major structural elements of the county have dominant trends, namely, northwest-southeast for the Parkersburg-Lorain syncline and Cambridge arch system and north-south for the Burning Springs anticline system. The Burning Springs anticline is paralleled on the west by the Parkersburg syncline. There seems never to have been a clear distinction made between this syncline and the northwest-trending Parkersburg-Lorain syncline, although maps prepared for this study indicate such a distinction would be desirable.

Mineral resources of the Washington County area include coal, oil and gas, sand and gravel, limestone, clay and shale, sandstone, molding sand, rock salt, and brine. Oil and gas, coal, and sand and gravel have the greatest current development and potential for immediate expansion. Clay and shale and salt have intermediate development potential which is governed by technology and the economy. Limestone, sandstone, molding sand, and brine have low development potential because of factors involving either quantity, quality, or the pressures of an expanding economy.

# Chapter 1

# INTRODUCTION

## GEOGRAPHY

Washington County, located on the Ohio River in southeastern Ohio (fig. 1), is the fifth largest county in Ohio, covers an area of 641 square miles, and is divided into 22 political townships of various sizes and shapes. The county is bordered on the west by Athens County and, clockwise from Athens, by Morgan, Noble, and Monroe Counties, Ohio, and Tyler, Pleasants, and Wood Counties, West Virginia.

Washington County lies between approximately 81°02′ and 81°52′ west longitude and between 39°11′ and 39°40′ north latitude. The county was mapped and subdivided by four different surveys: Old Seven Ranges, Congress Lands, Donation Tract, and Ohio Company Purchase. That portion of the county included in the Old Seven Ranges and Congress Lands surveys was divided into sections of approximately 1 mile square; the lands of the Ohio Company Purchase were divided into mile-square sections and 262-acre fractions, and the Donation Tract was divided entirely into an irregular system of lots. Details of the land subdivision systems applicable to Washington County are found in the excellent discussion by Sherman (1925).

The county occupies a position of considerable historical importance: it was the first county organized in the state of Ohio. Marietta (16,439 population, preliminary 1970), the county seat and principal city, was established in 1788 and was the first permanent settlement in Ohio and the Northwest Territory. Other important cities or villages, in decreasing order of population, are: Belpre (7,114), Beverly (1,363), New Matamoras (925), and Lowell (783). The area is served by U.S. 21, 50, and Alternate 50, Interstate 77, and a network of state routes. The Chesapeake and Ohio—Baltimore and Ohio Railroad systems serve the southern, central, and northwestern portions of the county, and the Penn Central Railroad serves the central and northern parts of the area. The Ohio River extends along the entire eastern and southern borders of the county and provides water transportation facilities. The Muskingum River, which traverses the area from the northwestern corner of the county to Marietta, was formerly used for commerce, but is now open only to pleasure craft.

## PURPOSE AND SCOPE OF INVESTIGATION

This report describes the rock and mineral resources of Washington County. Particular emphasis has been given those mineral resources which have or may have a potential for economic development. The information presented in this publication is the evaluation and summarization of several hundred measured stratigraphic sections, drillers' records of oil and gas wells, detailed descriptions of samples from oil and gas wells, geophysical logs of oil and gas wells, and previously published reports. Basic data concerning the geology of this area are on file with the Division of Geological Survey; interested parties may inquire there for further specific details. It is hoped that the data provided here will serve as a guide for exploration by the mineral industries, will strengthen the mineral economy of the county, and will provide a general information source for property owners and public officials in the Washington County area.

## PREVIOUS WORK

The authors wish to make special mention of a number of the previous works on the area. The first known writings on the geology of the area are by Hildreth (1825), who described briefly the soils, vegetation, topography, water, and rock and mineral resources; he established that the making of grindstones in this area was a flourishing industry as early as 1819. In 1838, in the first official report by the then newly organized Geological Survey, Hildreth discussed coal, limestone, and drainage features probably referable to the Teays system. Andrews (1874) presented the only attempt prior to this bulletin at a comprehensive report on the geology of the county. His work discussed briefly the principal geologic features and mineral resources for each township in the county. The work of Stout (1954), although it had limited distribution, added much additional information on the character and distribution of the geologically important Monongahela Group. Stauffer and Schroyer (1920) published the first detailed report on the Dunkard rocks of Ohio; these rocks are present throughout a substantial portion of the Washington County area. More recent work by Cross (1950), Cross, Smith, and Arkle (1950), Cross and Arkle (1951), and Arkle (1959) has added materially to knowledge of the Dunkard Group. A significant contribution to our understanding of drainage modifications in this region was made by Tight (1900, 1903). Small areas and individual beds have been mapped, and studies pertaining to mineralogy, petrography, sedimentation, stratigraphy, and geomorphology have been conducted in this area by several students pursuing advanced degrees in geology. Contributions of this type have been made by Bell (1950), Frye (1937), Kellenberger (1960), Martin (1949, 1955), B. E. Smith (1960), W. H. Smith (1948a), Stearns (1957), Thompson (1963), Thoms (1956), and Turrill (1960).

## ACKNOWLEDGMENTS

The authors have made liberal use of published and unpublished material gathered by many people, including the workers cited in the list of references and in the preceding discussion. We wish to acknowledge these workers and the contribution each of them has made through their reports and data on open file with the Division of Geological Survey. Special thanks are also extended to the late David K. Webb, Jr., for preparing the clay and shale discussion. Thanks are due Kenneth Reighard for the sand and gravel size-distribution curves. Karl V. Hoover assisted in the selection of sand and gravel and clay and shale localities and in the collection of samples.

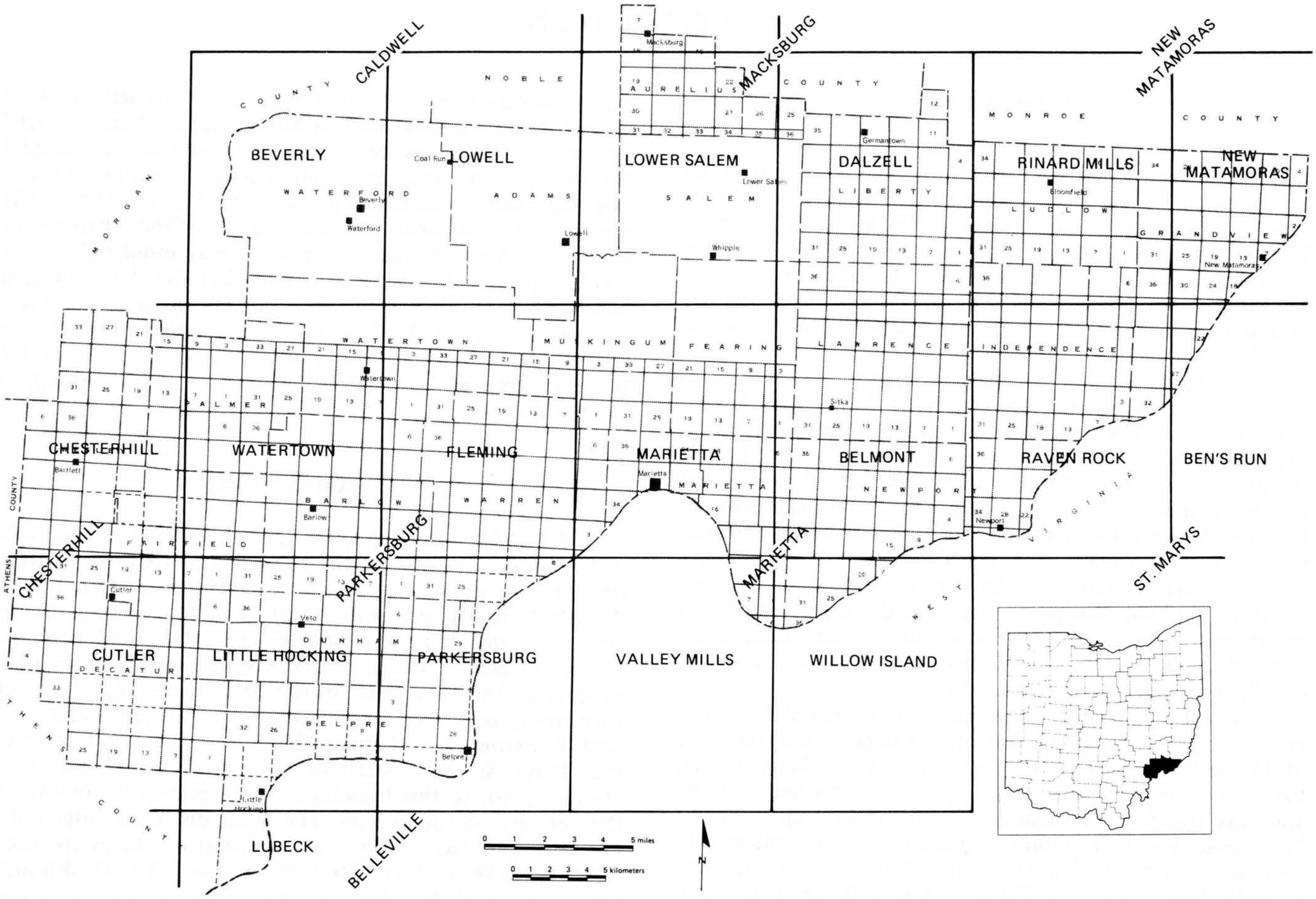


FIGURE 1.–Index map of 7½- and 15-minute topographic quadrangles for Washington County, Ohio.

# Chapter 2

## PHYSIOGRAPHY

### GENERAL STATEMENT

Washington County lies entirely within the Kanawha section of the Appalachian Plateaus province (Fenneman, 1938). This portion of the Appalachian Plateaus is described as being a mature plateau of fine texture with moderate to strong relief. The lowest elevation in Washington County is 564 feet above sea level; this is the normal pool level of the Ohio River at the point farthest downstream in the county. The highest point, near the former village of Glass in the extreme western part of sec. 27, Grandview Township, is slightly over 1,198 feet above sea level (pl.1). The maximum relief is thus 634± feet. However, the relief along the major streams is about 400 to 500 feet in the eastern part of the county and approximately 300 to 400 feet along the Muskingum River and along the southern reaches of the Ohio River. In general, the relief is much less in areas away from the major drainage lines.

A number of erosion surfaces (peneplains) have been identified in eastern Ohio and adjacent states. The general upland surface in Washington County lies to the south and west of the Flushing Escarpment and would appear to represent the Lexington (Worthington) surface (Stout and Lamb, 1938). This upland surface, although correlative with the Lexington, is at intermediate elevations with respect to the surfaces both east and west (Harrisburg and Lexington, respectively) of the Flushing Escarpment. Stout and Lamb (1938, p. 50) indicate this intermediate position:

> . . . west of the Flushing escarpment the Harrisburg peneplain level is identified by the higher ridge crests throughout much of the area. The common elevation, however, descends considerably below that in the highland area east of the Flushing escarpment. Throughout much of Carroll, Tuscarawas, Holmes, western Harrison, southwestern Ross, western Pike, and eastern Adams Counties many ridges reach the 1,260 foot level. In much of Coshocton, Guernsey, Muskingum, Noble, Washington, Morgan, Hocking, and Athens Counties they range between 1,100 and 1,260 feet, whereas in Meigs, Gallia, Lawrence, and Scioto Counties they seldom exceed 1,100 feet and many are much below this.

Further indication of the intermediate elevation of the highland area in Washington County is given by Cole (1934, p. 291):

> On the New Martinsville quadrangle [east of Washington County, adjacent to 15-minute New Matamoras quadrangle] a distinct level averaging about 1,400 feet in elevation is observed. Westward the elevations vary from 1,000 to about 1,200 feet. The highland area on the New Martinsville quadrangle is the continuation of the Allegheny peneplain into eastern Ohio. The broad, gently undulating surface westward is correlated with the Lexington surface, but does not record so great a reduction of the area as in southern Ohio and northern Kentucky. This surface is intermediate in character between the well developed Lexington peneplain and the broad strath stage which marks the typical Worthington surface of east-central and eastern Ohio.

The Parker Strath is a well-defined incipient erosion surface in Washington County and other sections of southern Ohio. Stout and Lamb (1938, p. 59) define it as

> an immature peneplain or erosion level, the work of streams during Teays time.

The Teays River system is discussed under preglacial and glacial drainage.

### MODERN DRAINAGE

The major stream in this region is the Ohio River (fig. 2). There are four principal interior streams, all of which join the Ohio River within the county boundaries. In decreasing order of area drained, they are the Muskingum River, the Little Muskingum River, Duck Creek, and the Little Hocking River. Wolf Creek, a major tributary to the Muskingum River, drains a larger area than does the Little Hocking River. Additional data on the total length, fall per mile, and drainage area of these as well as the minor streams of the area have been summarized in a report by Krolczyk (1954). A discussion of water supplies as related to the major streams will be found on page 130.

### PREGLACIAL AND GLACIAL DRAINAGE

The drainage system that existed prior to the advance of glacial ice into northern Ohio was considerably different from the present-day drainage system of Washington County and southern Ohio. Preglacial southern Ohio and adjacent areas of West Virginia and Kentucky were drained by a large north-to-northwest-flowing river system called the Teays (fig. 3). The blocking of this system by glacial ice in northern Ohio resulted in numerous drainage changes in the southern portion of the state. Many of these changes are quite obvious and have attracted the attention of geologists since the earliest days of geologic investigations in Ohio.

The earliest known observations on drainage modifications in Washington County were made by Hildreth (1838, p. 50):

> On Mr. Lawton's farm, in Barlow township, Washington county, in the midst of the marl region, is a locality of fossil fresh water shells, of the genus unio. They are imbedded in coarse sand or gravel, cemented by ferruginous matter. The specimens are casts, replaced by an argillaceous oxide of iron. The spot in which they are found has once evidently been the bed of an ancient lake or pond. It is now

a beautiful valley of a mile or more in width, by four miles in length, surrounded by low hills. On the south side, a small branch drains the superfluous water into the Little Hockhocking. In digging wells for domestic use, in this tract, beds of sand, gravel and plastic clay are passed to the depth of 30 feet, containing imbedded branches of trees, leaves and fragments of wood, of recent and living species. Similar valleys and levels are found in the uplands of the western part of the county, lying between the head waters of the creeks, and are a kind of table land. From the frequency of these flat lands between the head waters of the Little Hockhocking and the south branch of Wolf creek, it is quite possible that, at some remote period, the waters of Wolf creek were discharged into the Ohio river, instead of the Muskingum. This opinion is strengthened from the fact, that the head branches of the south fork now rise within two miles of the Ohio, and run northerly, parallel with, and opposite to, the course of the Muskingum for 12 miles, and joins that river, 20 miles from its mouth. The remains of its ancient beds would form pools and ponds of standing water, furnishing fit residences for the fresh water shells, whose fossil remains are now found there. Great changes have, evidently, been made in the direction of all our water courses, before they found their present levels.

The deposits to which Hildreth referred are found in the now-abandoned valleys of Barlow Creek and its tributaries (fig. 3). Plate 1 shows the extent of materials mapped as lake and stream deposits related to Barlow Creek. These materials correspond in part to the Minford silts (now Minford Silt) of Stout and Schaaf (1931).

Stout and others (1943, p. 52) described the Teays River system in the following terms:

The Teays, the master or at least the type stream of the system, gathered its headwaters out in the Piedmont Plateau of Virginia and North Carolina, flowed northward from [Asheville], North Carolina, to White Sulphur Springs, Virginia, thence northwestward across the mountains to Charleston, West Virginia. From Charleston its course was along the broad open Teays Valley past St. Albans, Milton, and Barboursville to what is now the valley of the Ohio River at Huntington. From this place the course of the Teays was much the same as that of the present stream, the Ohio River, to Wheelersburg, Ohio, where the two courses changed radically. From Huntington to Wheelersburg, however, the present stream did not obliterate all traces of the older Teays as the floor of the latter is well recognized by wide silted flats south of Ashland and by prominent terraces with typical accumulations between Franklin Furnace and Wheelersburg on the Ohio side.

The largest tributary river of the Teays system in southern Ohio was the Marietta River, of which Stout and Lamb (1938, p. 65) wrote:

. . . a stream that gathered its headwaters near Marietta, flowed southwestward past Parkersburg, West Virginia, Little Hocking, Coolville, Tuppers Plains and Chester, Ohio. . . . Some of the larger tributaries of the Marietta were the Albany River, Zaleski Creek, and Barlow Creek.

Two other important tributaries to the Marietta River were Whipple Creek and Rinard Mills Creek, which followed essentially the same courses as modern-day Duck Creek and

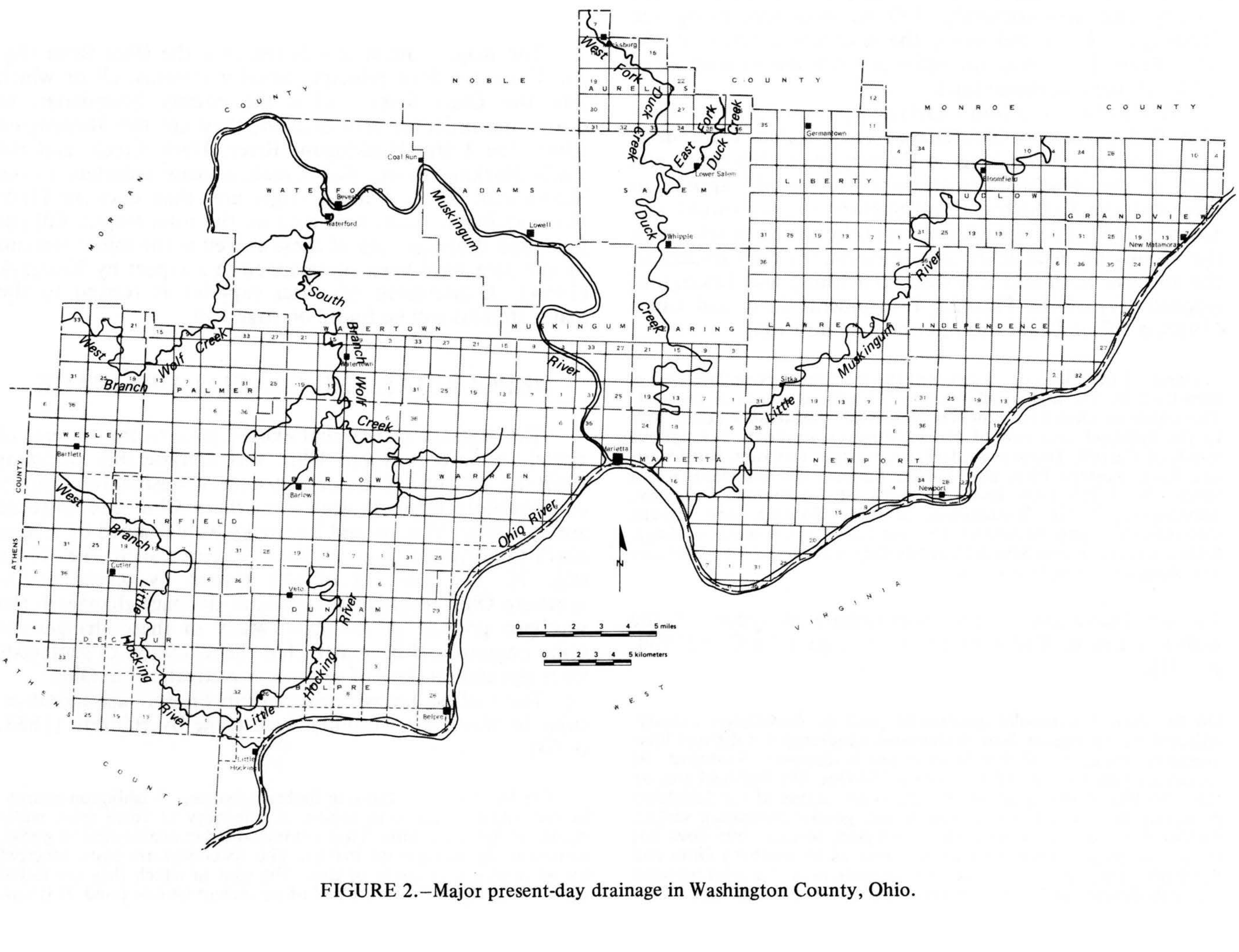


FIGURE 2.–Major present-day drainage in Washington County, Ohio.

the Little Muskingum River, respectively.

The details of the circumstances and conditions leading to the destruction of the Teays drainage system and the formation of the modern system are complex, and a detailed discussion is beyond the scope of this report. Briefly, however, the basic mechanism of this change was ice in the form of continental glaciers which invaded northern Ohio during the Pleistocene Epoch. There were at least three major ice advances in Ohio during the Pleistocene. The first of these blocked the preglacial northward-flowing Teays River system, thus starting a sequence of events leading to the formation of the modern south-flowing drainage system: the blockage of the north-flowing system by ice resulted in the formation of lakes in front of the ice sheet; glacial meltwaters fed the rising lakes until they broke over divides on the south and started an embryonic south-flowing drainage system. As the ice alternately advanced and retreated in northern Ohio, the streams were periodically blocked with ice and lakes were formed south of the ice front. After at least three repetitions of this sequence of events, stream piracy and downcutting of the divides were sufficient to establish permanently the south-flowing drainage pattern. The interested reader is referred to Stout and others (1943) for a comprehensive discussion of the development of the modern-day drainage system.

## PLEISTOCENE DEPOSITS

Unconsolidated materials of Pleistocene age are found in the major stream valleys and on upland flat areas (Parker Strath) in the western part of the county. These materials, all mapped with alluvium on plate 1, include stream and lake deposits of pre-Illinoian age, Wisconsinan sand and gravel deposited as outwash but derived from glacial deposits far to the north and northwest of the county, and Wisconsinan lake clays and silts.

### PRE-ILLINOIAN DEPOSITS

Sizable areas of unconsolidated fine-grained materials of probable pre-Illinoian age are found at elevations ranging from 740 to 900 feet in Barlow, Dunham, Fairfield, Palmer, and Watertown Townships (pl. 1). These deposits have been mapped largely as Holston (high-terrace phase) and Vincent silt loam soils by Phillips and others (1926), who (p. 20, 22) assigned an alluvial origin in old valleys to these soils. Both the Holston and Vincent silt loams are correlated in part with the Minford silts of Stout and Schaaf (1931).

Materials here lumped under the term Vincent silt loam undoubtedly represent both stream and lake deposition along the drainage line of Barlow Creek. Stout and others

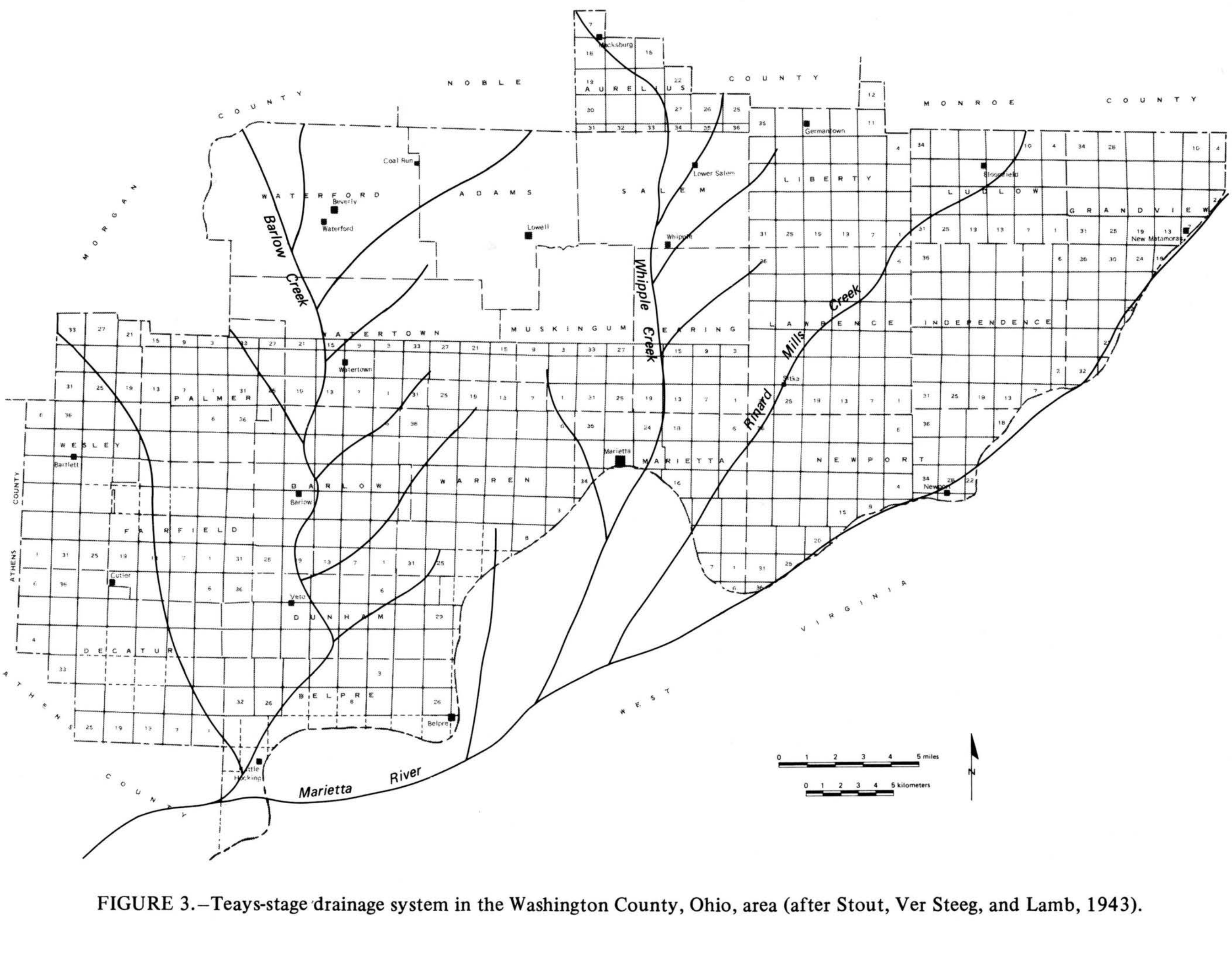


FIGURE 3.—Teays-stage drainage system in the Washington County, Ohio, area (after Stout, Ver Steeg, and Lamb, 1943).

(1943, p. 78) described the conditions under which the Vincent silt loam probably was deposited:

> Another effect of importance during the early stages of the damming of the Teays, Dover, Pittsburgh, and other rivers by the Kansan or pre-Kansan glacier was a flood period with the formation of long finger lakes in which was deposited the Minford silt from the fine materials long held in suspension and carried into the basins from headwaters areas, some far out in the Piedmont Plateau to the east.
>
> "Such silts in southern Ohio, in the Teays basin, are found at elevations as high as 840 feet and are thus plastered well up on the valley walls of these old streams the relief of which was from 250 to 300 feet, the usual position of the floors below the Lexington peneplain."

Materials mapped as Vincent silt loam range from moderately coarse ferruginous sand through silt to dominantly fine-grained laminated clay. Samples were collected at several localities for size-distribution analysis and for evaluation of economic potential. Collecting localities and results of these tests are cited in the discussions on molding sand and on clay in the mineral resources chapter.

## WISCONSINAN SAND AND GRAVEL

Wisconsinan glacial outwash, consisting primarily of sand and gravel, is found in both the Ohio and Muskingum River valleys. These deposits are discussed in detail in the section dealing with sand and gravel in the chapter on mineral resources.

## WISCONSINAN LAKE SILTS AND CLAYS

During Wisconsinan time the sand and gravel outwash that choked the valleys of both the Ohio and Muskingum Rivers to elevations above the outlet levels of the tributary streams served effectively to block drainage of those streams, and lakes were formed in which very fine-grained laminated silts and clays and poorly bedded silt and clay were deposited. Remnants of these deposits, as flat-topped terraces with surface elevations of 640 to 650 feet, are common in the valleys of Wolf and Duck Creeks and the Little Hocking and Little Muskingum Rivers.

Samples were collected from these terraces at several localities for size-distribution analysis, composition determinations, and evaluation of potential as ceramic raw material. Data on the chemistry, grain-size analyses, and ceramic properties are given in the clay discussion in the chapter on mineral resources.

# Chapter 3

## STRATIGRAPHY

### SURFACE STRATIGRAPHY

#### INTRODUCTION

Rocks of the Pennsylvanian and Permian Systems in the northern part of the Appalachian Basin, which includes eastern Ohio, have been divided into five major sequences on the basis primarily of practical considerations, that is, the presence of economically important coal beds. In this report these subdivisions, which in Ohio have been variously termed formations, series, groups, or measures, are considered to be groups. The Pennsylvanian System is comprised, in ascending order, of the Pottsville, Allegheny, Conemaugh, and Monongahela Groups. All Permian rocks are assignable to the Dunkard Group; however, the lower portion of the Dunkard includes a transitional sequence of Pennsylvanian- and Permian-age rocks. In Washington County an aggregate thickness of approximately 1,100 feet of rock, ranging from the mid-Conemaugh Group through the Dunkard Group, is exposed (fig. 4).

There has been considerable controversy over nomenclature and positions of boundaries used to describe and delineate the Pennsylvanian and Permian groups. An exhaustive discussion of the history and problems of classification and nomenclature is not deemed applicable to this report; however, useful information on this subject will be found in the following works: Berryhill (1963), Berryhill and Swanson (1962), Prosser (1901, 1905), Rogers (1858), and Sturgeon (1958). Table 1 outlines in abbreviated form the history of the classification and nomenclature applied in the northern Appalachian region. A brief discussion of the Permian-Pennsylvanian systemic boundary problem will be found in the description of the Permian System.

Stout (1931, p. 197-198) pointed out that a threefold subdivision of the Pennsylvanian of Ohio could be made, although this suggestion has received little attention. He stated:

> The limestones and fossil-bearing calcareous shales are of marine or brackish water origin, from the Harrison [ore, basal Pennsylvanian] to the Strasburg coal; are of either marine or fresh water origin from the Strasburg coal to the Skelley limestone; and are entirely of fresh water origin from the Skelley to the Waynesburg coal. The gradation is thus from marine origin, through marine and fresh water, to fresh water origin alone. If any division of the Pennsylvanian system into large units is to be made, this one seems to be the most logical.

Stout also cited changes in the ceramic quality of the clays and in the occurrence of bedded iron ores (clay ironstone); these changes, which correspond essentially to his subdivisions, he considered to be further evidence of the tripartite nature of the Pennsylvanian of Ohio.

#### STRATIGRAPHIC TREATMENT

In the northern Appalachian Basin numerous discrete thin lithologic units in both the Pennsylvanian and Permian Systems have been given formal names (Stout and others, 1943, p. 108). These units have been variously designated members, beds, or formations. Although some of the named units may warrant member designation, in this report the authors consider them to be beds as defined by the American Commission on Stratigraphic Nomenclature (1961). Over 60 such beds have been named in Ohio in the interval from mid-Conemaugh through the Dunkard Group. In addition, there are many units, mostly shales but also a few sandstones, which have not been named.

The large number of named units of the Pennsylvanian and Permian of Ohio is related in part to the early geologic concept that sedimentary rock units were tabular in nature and could be traced or correlated over a large geographic area. Geologic work based on this concept is informally called "layer-cake" geology. This concept as applied to the Pennsylvanian rocks of Ohio was aided by the fact that, although most do not, there are a few beds which do have a reasonably large areal extent; in addition, because of the repetitive nature of the sequence, many beds have a general though not precise relationship with similar beds at a different locality. The latter case is recognized by statements such as "a coal in the position of the Pittsburgh seam is . . ." or "the position of the Sewickley sandstone is occupied by . . ." The proliferation of named units was also in part a response to the need of an industrial society to have identifying terms to use in the exploitation and development of the region's mineral resources. Reasonably accurate correlations of named beds from one area to another greatly aided the early development of the coal-measure resources of eastern Ohio; in this respect the naming and correlating of relatively thin stratigraphic units such as coal smuts still has value.

A subsequent stratigraphic concept was that of the cyclothem, as formulated by Weller (1930) and Wanless and Weller (1932). The cyclic concept recognizes and attempts to structure into groups called cyclothems the repetitive sequences of coals, shales, limestones, clays, sandstones, and other rock types characteristic of the coal measures. The "classical" cyclothem is considered to consist of, from bottom to top: (1) sandstone with a disconformable base, (2) shale, (3) freshwater limestone, (4) underclay, (5) coal, (6) marine shale, (7) marine limestone, and (8) marine shale with a disconformable top, which marks the beginning of the next cyclothem. In Washington County a more "typical" cyclothem would consist of, from bottom to top: (1) sandstone with a locally disconformable base, (2) mudstone, generally with limy nodules, (3) freshwater limestone, in many cases nodular and in many places absent, (4) underclay, generally very thin, (5) coal or coaly shale, and (6) shale with locally disconformable top, marking the beginning of the next cycle. Most workers have treated cyclothems in much the same fashion as earlier workers treated individual beds, resulting in widespread correlation of individual cyclothems throughout the Pennsylvanian and Permian Systems; the lack of widespread continuity of individual beds has resulted in a relatively large number of variations from the "classical" cyclothem. Even with the many cited variations there still seem to be the same correlation problems inherent in the classical "layer-cake" approach.

Sturgeon (1958) and Flint (1951) have made use of the cyclothem in describing stratigraphic sequences in nearby Athens and Perry Counties; however, in Washington County, although the authors found the cyclic concept to be a great aid in field work, they felt that the formal cyclothem, or variations of it, was not adequate to portray the stratigraphy of the area. Rapid facies changes are the norm, and most beds do not have good lateral continuity (pls. 2-6, 9). The general lack of distinctive lithologic and faunal differences made it necessary to correlate and map on the basis of gross lithologic characteristics and sequence of occurrence (*i.e.*, stratigraphic position).

More recent work in the Pennsylvanian of the northern Appalachian Basin has demonstrated the close similarities between the sedimentary framework of these rocks and the sediments of modern deltas. These similarities are so great that Ferm and Cavaroc (1969), in a field guide describing the deltaic characteristics of the Allegheny rocks in the upper Ohio River valley, stated that

> . . . comparisons between sequences and lateral changes of the Pennsylvanian model and those known from the recent Mississippi River deposits show such close similarity that some of the terminology indicating specific recent environments [is] also included on the diagram.

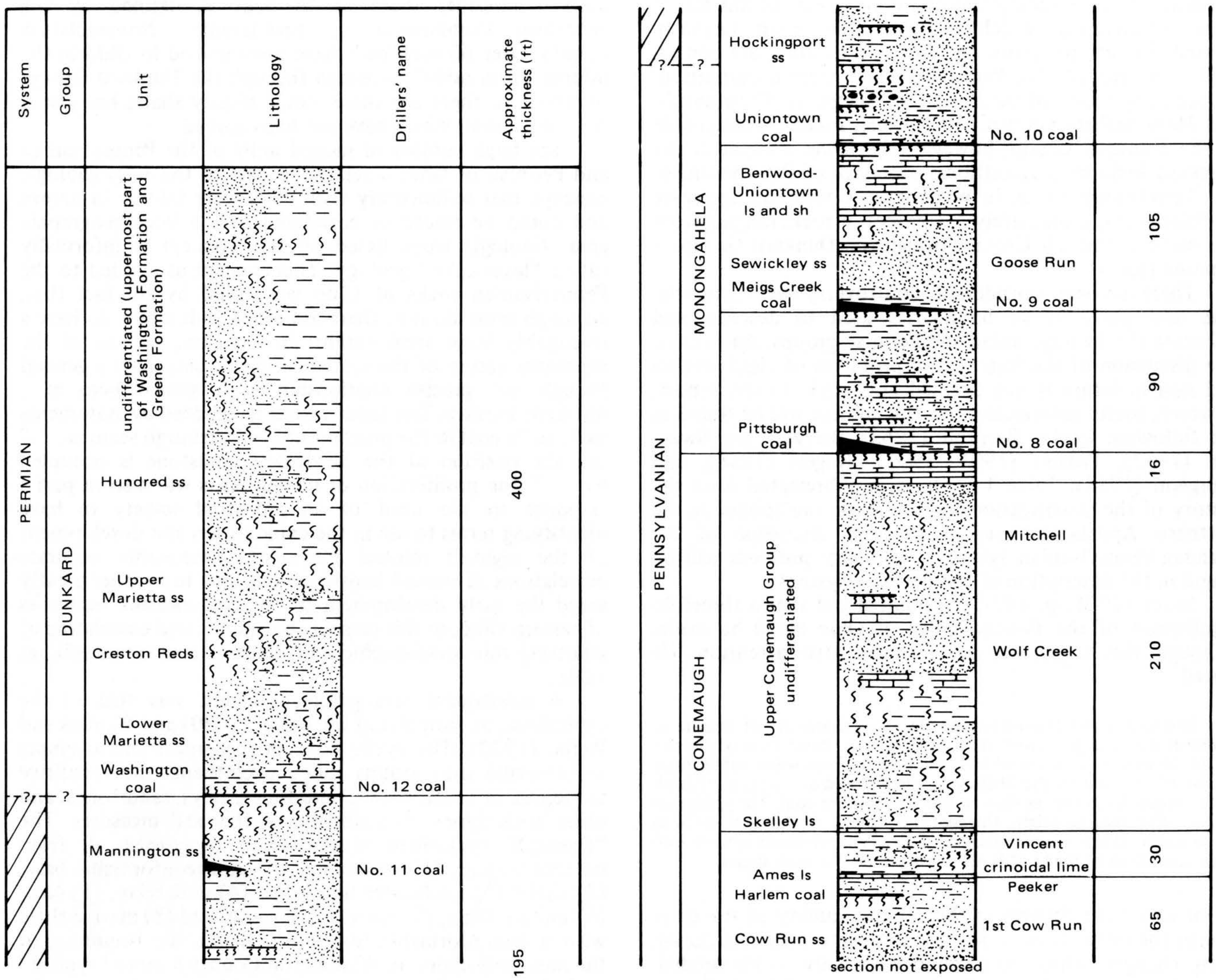


FIGURE 4.–Generalized stratigraphic column for the surface rocks of Washington County, Ohio.

TABLE 1.—*Abbreviated history of the stratigraphic nomenclature of Pennsylvanian and Permian rocks in the northern Appalachian Basin*

| | Rogers, 1858 (Pennsylvania) | Various authors, 1840-1891 (primarily Pennsylvania) | | O'Harra, 1900 (Maryland) | Prosser, 1905 (Ohio) | Berryhill and Swanson, 1962 (Pennsylvania) | |
|---|---|---|---|---|---|---|---|
| PERMIAN | Upper Barren Measures | Greene Co. Group (Stevenson, 1876) | Dunkard Creek Series (White, 1891) | Dunkard formation | Dunkard formation | Permian | Greene formation |
| | | | | | | | (Upper Washington Coal) |
| | | | | | | | Washington formation |
| | | | | | | | (Washington coal) |
| | | Washington Co. Group (Stevenson, 1876) | | | | Perm. and Penn. | Waynesburg formation |
| | | | | (Waynesburg coal) | (Waynesburg coal) | | (Waynesburg coal) |
| PENNSYLVANIAN | Upper Productive or Newer Coal Measures | Monongahela Series (Rogers, 1840) | | Monongahela formation | Monongahela formation | Pennsylvanian | Uniontown formation |
| | | | | | | | (Uniontown coal) |
| | | | | | | | Pittsburgh formation |
| | | | | (Pittsburgh coal) | (Pittsburgh coal) | | |
| | Lower Barren or Older Coal-Shale | Allegheny Series (Rogers, 1840) | Conemaugh Series (Platt, 1875) | Conemaugh formation | Conemaugh formation | | |
| | | | | (Upper Freeport coal) | (Upper Freeport coal) | | |
| | Lower Productive or Older Coal Measures | | Allegheny River Series (Stevenson, 1873; Platt, 1875) | Allegheny formation | Allegheny formation | | |
| | | | | (Brookville coal) | (Brookville coal) | | |
| | Seral Conglomerate | Pottsville Seral Conglomerate (Lesley, 1876) | | Pottsville formation | Pottsville formation | | |

A major contribution to the development and understanding of the "delta concept" as applied to the Pennsylvanian of Ohio has been made through dissertations and studies by J. C. Ferm and students.

The authors could recognize some deltaic aspects of the surface rocks of Washington County. However, to gain an understanding of the deltaic framework in this area would involve extensive regional study far beyond the borders of the county and thus beyond the scope of the present study. An effort has been made, therefore, to indicate the "non-layer-cake" nature of the surface stratigraphy while using some aspects of the older concepts. The existing nomenclature and stratigraphic classification, although based on an older and less accurate concept, are deemed useful in a report of this type until enough work is done with the new concepts in mind to provide a basis for reference. Rock units which have little or no economic potential or which are limited in areal distribution and are obviously not best treated as widespread tabular bodies are given little attention in this report. Those stratigraphic units having possible economic potential or widespread distribution in the county are discussed, along with those that are important in the "classical" framework of reference.

## GENERAL DESCRIPTION OF SURFACE ROCKS

The exposed upper Pennsylvanian strata and the Permian strata of Washington County consist of a repetitive sequence of mudstones, sandstones, and siltstones with lesser amounts of limestones, shales, coals, and clays. The calcareous units are, with a single exception, all of fresh-water origin. The exposed sequence as a whole essentially corresponds to Stout's (1931, p. 197-198) Upper Division. Examination of the records and exposures for Washington County indicate no readily apparent compositional differences between units of the same lithologic type, and variation through the section is a matter of relative abundance of rock types.

The term "mudstone" is used in this report to designate units that are essentially nonbedded, break with an irregular fracture, are generally calcareous with limy nodules, are semiplastic to nonplastic, and consist predominantly of clay- and silt-size particles. Beds of this type have been called "clay-shale," "shale," "marl," and "red beds" by previous workers in southeastern Ohio. Mudstones of the Washington County area are predominantly red or some shade of red, with green to greenish-gray mottling common. In most places these units are complexly interbedded with siltstones and with lenses of fine-grained sandstone. Travertine coatings are common on the surfaces of the interbedded sandstones.

Sandstones range from massive to shaly bedded and from very fine to coarse grained and conglomeratic. They are generally light greenish gray to blue gray when unweathered and buff to light brown when weathered. Crossbedding is common. Compounds of iron, calcium, or silica are the common cementing agents. Unpublished theses on the petrography of a number of sandstones in the area indicate that these units have a mineralogic composition of 62 to 90 percent quartz, 2 to 21 percent clay and silt, 0.1 to 1 percent heavy minerals, 2 to 10 percent feldspar, 1 to 8 percent mica, and 1 to 9 percent rock fragments (Martin, 1949, 1955; Thompson, 1963; Thoms, 1956; Turrill, 1960). Most sandstones in the Washington County area are lenticular, and the major sand bodies are elongate in a roughly northwest-southeast direction (figs. 7, 13, 16).

Siltstones are generally not present as thick discrete rock units, but are most commonly interbedded with shaly sandstones.

Marine limestone is present in a single exposure along the axis of the Newell Run anticline. The Ames and Skelley(?) units at this localized outcrop consist of fossiliferous thin medium-crystalline to coarsely crystalline dark-gray to dark-greenish-gray limestone. Most workers have considered that the limestones above the Skelley were deposited in a brackish to freshwater environment, and the authors found no evidence to the contrary.

The nonmarine limestones are commonly present as thin beds, generally not exceeding 2 or 3 feet in thickness, interbedded with a fraction of an inch to a few inches of calcareous mudstone and shale. In a few places the limestone beds aggregate 10 or 12 feet. Limestone is common also as irregular nodular zones or as scattered nodules in mudstones. The nonmarine limestones range from light to dark gray on fresh surfaces to yellowish gray on weathered surfaces and are generally cryptocrystalline to very finely crystalline and homogeneous. They normally have a relatively high clay content, causing them to break down readily on weathering. In many places these limestones are conglomeratic or brecciated, with both matrix and pebbles composed of similar material. Hyde (1908) referred to limestones exhibiting this feature as desiccation breccias.

The shales of Washington County overlie coals or carbonaceous clay zones or are intimately interbedded with sandstones and siltstones. For the most part, they are thin to medium bedded and range in color from light to dark gray through olive green to red. Many of the early workers in eastern Ohio did not distinguish clearly between the nonbedded mudstones and the bedded shales; both rock types were commonly referred to as shales.

High-ash–high-sulfur coals ranging from 1 to 96 inches in thickness are found throughout the county. Very few of them, however, exceed 1 foot in thickness. Many of the coals are very shaly, perhaps better described as coaly shale, and in many places are separated into two or more benches by clay or shale partings. Carbonaceous clayey zones, designated "smuts," are thought to be lateral representations of coal-forming environments. Even though they are normally only a fraction of an inch to a few inches thick, smuts are recognized easily and in many cases provide a basis for local correlations.

Thin underclays, a few inches to a few feet thick, are present under coals in most localities throughout the county. The underclays are plastic to semiplastic, light to dark gray, nonbedded, and generally noncalcareous. Some clays grade downward into mudstones; however, the latter are distinguished by their red color, lack of plasticity, and calcareous nature.

## PALEONTOLOGY

Fossil material is relatively abundant in the upper Pennsylvanian and the Permian of the Appalachian Basin, but has received little attention. In Washington County, freshwater invertebrate, vertebrate, and plant fossils are a common although not an obtrusive feature of the exposed rocks.

Both invertebrate and vertebrate remains are found most commonly in the limestones and shales associated with coals or smuts. Pelecypods, ostracods, conchostracans, *Spirorbis,* and small gastropods as well as fish teeth and plates were found throughout the section, most noticeably in association with the Uniontown and Pittsburgh coals. For the most part, however, the fauna is a diminutive one and can easily be overlooked. Stauffer and Schroyer (1920, pl. XI) pictured a few "fresh-water" invertebrates from the Dunkard.

Vertebrate remains are generally badly broken up: no complete or even nearly complete skeletons have been found. Paleoniscoid fish "hash" is found with regularity in the limestones and shales overlying coals, and coprolites and bone fragments have been found throughout the section. Olson (1970) listed several species, representing fish, reptiles, and amphibians, found at Belpre. A badly crushed specimen of bone, possibly from the skull of an embolomerous-type labyrinthodont (D. Baird, personal communication) was found in a stratigraphic position tentatively correlated with the position of the Washington coal. The specimen was found in Watertown Township (O.G.S. section 2984R) and has been deposited in the Princeton University collection (catalog no. PU 19300).

Plant impressions and compressions are common in the well-bedded shales and are present in most of the shales overlying the coals and smuts. Casts and molds of stems or trunks are less common, but are found in some siltstones and sandstones. Many of the forms common to this region are pictured by Cross and Schemel (1956a, p. 85, 87, 989); the Dunkard forms are further pictured and discussed at some length by Cross (1958, p. 191-197). Plant spores are extremely abundant in the coals and coaly shales and have recently been the subject of considerable study. The interested reader is referred to the palynological papers of Clendening (1960, 1962, 1967, 1968, 1969a,b, 1970a,b,c) and of Cross and Schemel (1952).

## PENNSYLVANIAN SYSTEM: CONEMAUGH GROUP

### GENERAL CHARACTER

Rocks of the upper half of the Conemaugh Group crop out in limited areas of Aurelius, Lawrence, Ludlow, Salem, and Newport Townships. These rocks are above drainage in the valleys of Duck Creek and its major tributaries (pl.1) from central Salem Township northward to the Noble County line. They are exposed also on the crest of the Cow Run anticline in secs. 19 and 20 of Lawrence Township (pl. 1). North of Sitka, the uppermost 10 to 20 feet of the Conemaugh may be seen in places along Fifteenmile Creek and the Little Muskingum River as far north as Flints Mill (now called Bloomfield); most of these outcrops are too thin to be shown on plate 1. Conemaugh strata are also exposed along the axis of the Newell Run anticline in Newport Township just west of the village of Newport. The greatest exposed thickness of Conemaugh rocks in the county is present in this vicinity; an aggregate interval of about 320 feet of strata, from just below the Cow Run sandstone to the Pittsburgh coal, is above drainage (fig. 4).

The Conemaugh of Washington County consists for the most part of poorly exposed sandstones, mudstones, siltstones, shales, thin limestones, clays, and coals. The relatively thick incompetent varicolored mudstones slump readily and are largely responsible for the poor exposures. With the exception of the Ames limestone, all units are characterized by lack of lateral continuity and by various thicknesses. In general, the beds above the Ames limestone are considered to be of nonmarine origin, although in places marine fossils are found as high as 40 to 50 feet above the Ames (see p. 55). The highest marine unit which crops out in Washington County is found about 28 feet above the Ames and is tentatively identified as the Skelley limestone. Nonmarine ostracods, pelecypods, and small gastropods, and *Spirorbis* are relatively abundant in limestones of the upper half of the group.

Stout and others (1943) included, in ascending order, the following 36 named units in the Conemaugh of Ohio: (1) Lower Mahoning sandstone or shale, (2) Mahoning limestone, (3) Thornton clay, (4) Mahoning (No. 7A) coal, (5) Upper Mahoning sandstone or shale, (6) Mason coal, (7) Brush Creek coal, (8) Brush Creek limestone, (9) Buffalo sandstone, (10) Wilgus coal, (11) Cambridge limestone, (12) Bloomfield limestone, (13) Anderson coal, (14) Portersville limestone, (15) Cow Run sandstone, (16) Ewing limestone, (17) Barton coal, (18) Saltzburg (Saltsburg) sandstone, (19) Round Knob (Pittsburgh) clay, (20) Harlem coal, (21) Ames limestone, (22) Gaysport limestone, (23) Duquesne coal, (24) Skelley limestone, (25) Birmingham shale, (26) Elk Lick limestone, (27) Elk Lick coal, (28) Morgantown sandstone, (29) Clarksburg limestone, (30) Clarksburg coal, (31) Connellsville sandstone, (32) Summerfield (Lower Pittsburgh) limestone, (33) Lower Little Pittsburgh coal, (34) Bellaire sandstone, (35) Upper Little Pittsburgh coal, and (36) Upper Pittsburgh limestone.

Only those units identified in Washington County are discussed.

## DESCRIPTION OF UNITS

### Cow Run sandstone to Skelley limestone

The lowest named stratigraphic unit reported to crop out in Washington County is the Cow Run sandstone. Andrews (1874, p. 502), speaking of the Newell Run anticline area, stated that, "The sandrock in which the old Newton well, on Cow Run, found its oil, is here seen in the Ohio River bank." He gave the following section (cumulative thickness figures supplied), measured near the mouth of Conley's Run:

| | ft | in | ft | in |
|---|---|---|---|---|
| 1. Fossiliferous limestone [AMES limestone of this report] | 1 | 6 | 68 | 8 |
| 2. Yellow shales | 18 | 0 | 67 | 2 |
| 3. Slaty coal | 0 | 8 | 49 | 2 |
| 4. Clay and coal [HARLEM coal of this report] | 0 | 6 | 48 | 6 |
| 5. Fire-clay, light-colored | 0 | 6 | 48 | 0 |
| 6. Coal | 0 | 6 | 47 | 6 |
| 7. Not exposed | 20 | 0 | 47 | 0 |
| 8. Sandrock, with some quartz pebbles, first oil rock of Cow Run | 25 | 0 | 27 | 0 |
| 9. Iron ore adhering to sandrock | 0 | 6 | 2 | 0 |
| 10. Blue clay shale, with nodules of iron ore | 1 | 6 | 1 | 6 |
| Level of water Ohio River | | | | |

This section is very similar to the following section from a well reported by Andrews (1874, p. 497) from the area of the Cow Run anticline, 5 miles to the northwest. This well, (the log of the upper 169+ feet is given here; cumulative thickness figures supplied), is reported to have started 140 feet below the Pomeroy (Pittsburgh of this report) coal.

| | ft | in | ft | in |
|---|---|---|---|---|
| 1. Alluvial | 22 | 0 | 169+ | 6+ |
| 2. Red and blue shales | 74 | 0 | 147+ | 6+ |
| 3. Fossiliferous limestone [AMES limestone of this report] | 1 | 6 | 73+ | 6+ |
| 4. Yellow shale | 18 | 0 | 72+ | 0+ |
| 5. Coal (no measurement) [HARLEM coal of this report] | | | | |
| 6. Not given | 20 | 0 | 54 | 0 |
| 7. First sandrock, oil rock of Newton well | 30 | 0 | 34 | 0 |
| 8. Clay ("mud rock"), with nodular iron ore | 4 | 0 | 4 | 0 |

Andrews measured his Conley's Run section before locks and dams were installed on the Ohio River and before a modern highway was built between the river and valley wall. An examination of the section in the new highway cut did not offer any new information on the Cow Run sandstone, but did provide additional data on the rocks above the Harlem coal. The following section[2] records a fossiliferous marine limestone, tentatively identified as the Skelley limestone, approximately 28 feet above the Ames.

O.G.S. 15327, Newport Twp., N½ of the NW¼ sec. 33E, Belmont 7½- and Marietta 15-minute quadrangles. Section measured 1¼ miles west of Newport, Ohio, on north side of Ohio Rte. 7. Measured by H. R. Collins, and B. E. Smith. Base elevation 640± feet (topographic map).

| | ft | in | ft | in |
|---|---|---|---|---|
| 19. Sandstone, buff, fine- to medium-grained, shaly to massive | 20 | 0 | 84 | 9 |
| 18. Mudstone, variegated, nonbedded, calcareous; with limestone nodules and 10-inch limestone beds; shaly sandstone at base | 10 | 0 | 64 | 9 |
| 17. Limestone, dark-greenish-gray, hard, dense, crystalline, fossiliferous, marine; mottled purple; sparse crinoid stems. SKELLEY | 1 | 0 | 54 | 9 |
| 16. Shale and sandstone interbedded, greenish-gray, thin-bedded to massive, iron-stained, micaceous | 23 | 11 | 53 | 9 |
| 15. Mudstone, dark-gray to black, massive-bedded, micaceous; nonfossiliferous limestone nodules scattered throughout | 4 | 0 | 29 | 10 |
| 14. Shale, black, carbonaceous, thin-bedded, fossiliferous, marine; becoming massive upward | 0 | 6 | 25 | 10 |
| 13. Limestone, dark-gray, carbonaceous, hard, dense, massive, fossiliferous, marine; irregular thickness; coaly debris at base. AMES | 1 | 0 | 25 | 4 |
| 12. Coal, bright, blocky, good cleating. AMES | 0 | 6 | 24 | 4 |
| 11. Mudstone, medium- to dark-gray, nonbedded, highly iron-stained, silty; limestone scattered throughout | 3 | 0 | 23 | 10 |
| 10. Shale, black, carbonaceous, plant-fossiliferous, micaceous | 0 | 1 | 20 | 10 |
| 9. Sandstone and shale interbedded, greenish-gray to buff, massive to bedded | 3 | 0 | 20 | 9 |
| 8. Shale, black, carbonaceous, fissile, plant-fossiliferous, micaceous | 0 | 1 | 17 | 9 |
| 7. Sandstone and shale interbedded, greenish-gray to buff, massive to bedded, extremely arenaceous; limestone nodules and lenses in upper portion; plant fossils in the shale lenses | 4 | 6 | 17 | 8 |
| 6. Shale, greenish-gray, medium- to massive-bedded, sandy, micaceous, plant-fossiliferous | 2 | 6 | 13 | 2 |

[2]Some stratigraphic sections included in this report have been slightly edited for greater consistency of language. Unit thicknesses and cumulative thicknesses from the base of the section are reported.

| | ft | in | ft | in |
|---|---|---|---|---|
| 5. Coal, blocky, bright; with dull bony layers | 0 | 8 | 10 | 8 |
| 4. Clay, light- to medium-gray, plastic, nonbedded | 0 | 3 | 10 | 0 |
| 3. Coal, blocky, bright; with dull bony layers. HARLEM | 0 | 7 | 9 | 9 |
| 2. Clay, greenish-gray, nonbedded, hard, compact, micaceous | 1 | 8 | 9 | 2 |
| 1. Covered interval to road level of Ohio Rte. 7 | 7 | 6 | 7 | 6 |

The rocks between the Cow Run sandstone and the Skelley limestone are brought to the surface on the crest and sides of the north-plunging Newell Run anticline in a very small area of secs. 3, 4, and 33E of Newport Township. Because these units are principally below drainage throughout the county, a discussion of the Skelley and lower beds is given in the description of subsurface units.

### Skelley limestone to Upper Pittsburgh limestone

Approximately 210 feet of strata between the Skelley and Upper Pittsburgh limestones crop out in Newport Township. However, because of slumping and creep caused by the generally incompetent character of the rocks in this portion of the section, there are only limited exposures. The few data available indicate that the sequence consists of massive sandstone, varicolored mudstones ("redbeds"), clayey freshwater limestones, and shale. Mudstones probably comprise an appreciable portion of the sequence, as elsewhere in Ohio. The following stratigraphic section illustrates in part the nature of the rocks in Newport Township:

O.G.S. 6632, Newport Twp., NW¼ of the NW¼ sec. 33E, Belmont 7½- and Marietta 15-minute quadrangles. Measured from Ohio River to top of a prominent spur in the SW¼ of the SW¼ sec. 34E. Measured by W. H. Smith. Base elevation 589 feet (altimeter).

| | ft | in | ft | in |
|---|---|---|---|---|
| 1. Poorly exposed, shale with siltstone showing | 14 | 6 | 264 | 6 |
| 2. Sandstone, light-gray to buff, medium- to coarse-grained, slightly calcareous, very hard, tough, massive; weathering light buff; no prominent bedding; forming prominent cliffs; basal contact quite undulating, probably representing disconformity | 21 | 6 | 250 | 0 |
| 3. Concealed | 5 | 8 | 228 | 6 |
| 4. Limestone, gray to purplish, clayey, poorly exposed; containing minute gastropods (not identified) | 0 | 10 | 222 | 10 |
| 5. Poorly exposed; apparently marly limestone, shale, and mudstone, badly slumped and weathered | 20 | 6 | 222 | 0 |
| 6. Concealed; apparently largely the same as units 5 and 7 | 6 | 6 | 201 | 6 |
| 7. Marly limestone (or mudstone), drab-green to purplish; weathering pink to red; with many pellets of hard light-colored limestone up to 1 inch in diameter; poorly exposed | 44 | 0 | 195 | 0 |
| 8. Covered interval | 11 | 0 | 151 | 0 |
| 9. Sandstone, light-gray, highly calcareous, medium-grained, very hard | 11 | 4 | 140 | 0 |
| 10. Sandstone, gray-green, very fine-grained; weathering platy; base concealed | 4 | 8 | 128 | 8 |
| 11. Concealed, red clay earth showing | 24 | 6 | 124 | 0 |
| 12. Siltstone, drab-greenish-tan, shaly | 13 | 0 | 99 | 6 |
| 13. Shale, red, and siltstone, very poorly exposed | 3 | 6 | 86 | 6 |
| 14. Shale, gray | 1 | 0 | 83 | 0 |
| 15. Limestone, dark-gray, very hard, highly fossiliferous; weathering brown. AMES | 1 | 2 | 82 | 0 |
| *Describer's correlation of units above the Ames limestone omitted for purposes of this discussion; units 16 through 22 also omitted* | | | | |

The uppermost portion of the Conemaugh was well exposed in a number of short sections along recently opened strip mine haul roads in northern Aurelius Township. The following section is representative:

O.G.S. 15276, Aurelius Twp., SW¼ of the SW¼ sec. 28, Lower Salem 7½- and Macksburg 15-minute quadrangles. Measured along abandoned strip mine road leading from abandoned township road from SW¼ to center of sec. 28. Measured by H. R. Collins and B. E. Smith. Base elevation 680- feet (topographic map).

| | ft | in | ft | in |
|---|---|---|---|---|
| *Units 12 through 24 omitted* | | | | |
| 11. Coal. PITTSBURGH (laterally, in places, this zone gives way to red mudstone with smutty clay) | | | 71 | 11 |
| Coal, bony, shaly; vitrain streaks | 0 | 2 | | |
| Clay, light-gray, plastic | 0 | 2 | | |
| Coal, bony, shaly; vitrain streaks | 0 | 3 | | |
| 10. Mudstone, light- to medium-gray, nonbedded, silty | 1 | 0 | 71 | 4 |
| 9. Clay, light- to medium-gray; carbonaceous in places, bedded where carbonaceous | 0 | 1 | 70 | 4 |
| 8. Mudstone, variegated purple, red, light- to medium-gray, nonbedded, weathered | 5 | 8 | 70 | 3 |
| 7. Mudstone and sandstone, interbedded; mudstone, olive-drab, nonbedded, sandy; at 10 feet 8 inches into unit sandstone, buff, massive to slabby, fine- to medium-grained; top contact gradational | 20 | 8 | 64 | 7 |
| 6. Covered | 8 | 8 | 43 | 11 |
| 5. Shale, chocolate-red, olive-green, thin-bedded; top covered | 1 | 0 | 35 | 3 |
| 4. Clay, light- to medium-gray; carbonaceous in part, bedded where carbonaceous; coal horizon(?) | 0 | 3 | 34 | 3 |
| 3. Mudstone, olive-green to drab, red-mottled, nonbedded; weathering gray; small siltstone lenses | 8 | 1 | 34 | 0 |
| 2. Covered | 5 | 4 | 25 | 11 |
| 1. Sandstone, light-gray to buff, massive, medium- to coarse-grained, friable | 20 | 7 | 20 | 7 |

### Upper Pittsburgh limestone

The Upper Pittsburgh limestone is persistently present below the Pittsburgh coal outcrop in Adams, southeastern Aurelius, Fearing, Lawrence, Ludlow, and Salem Townships. Its position relative to the Pittsburgh coal was first noted by Andrews (1869, p. 128-129), and it was named by White (1891, p. 87). The unit consists of a pelecypod-bearing carbonaceous to coaly medium-gray limestone broken by numerous shale interbeds. Individual beds are thin, ranging from a few inches to a few feet; aggregate thickness may be as much as 16 feet. The mollusks were first noted by Andrews also; subsequent workers have, for correlation purposes, made extensive use of their presence here and in the slightly higher Redstone limestone. A discussion of the Upper Pittsburgh as a potential source of limestone is given in the mineral resources chapter.

In most of Aurelius Township a calcareous mudstone with limy nodules and scattered beds of rubbly limestone is found in the position of the Upper Pittsburgh. The preceding stratigraphic section (O.G.S. 15276) illustrates the nature of the unit there. Stratigraphic sections 8820 (p. 15). 8220 (p. 112), and 8199 (p. 17) show the general character of the unit at different points in the county.

## PENNSYLVANIAN SYSTEM: MONONGAHELA GROUP

### GENERAL CHARACTER

The Monongahela Group crops out along the major valleys throughout the area north and east of the Muskingum River and along the western border of the county (pl. 1). This group is lithologically similar to both the overlying and underlying groups, with sandstones, mudstones, shales, limestones, coals, and clays comprising the sequence. In addition, unlike the adjacent groups, it includes a number of mineable coals and relatively thick freshwater limestones. The presence of mineable coals in this group was the basis for its original classification (Rogers, 1858, p. 16-20) as the Upper Productive Coal Measures (table 1).

The Monongahela Group, as traditionally defined in Ohio, includes all strata from the base of the Pittsburgh coal to the top of the Waynesburg coal. This sequence is the equivalent of the Monongahela River series of White (1891, p. 43). In Washington County the Waynesburg coal is absent in many places and is identified only with difficulty in other parts of the area. A thin smut is found in most of the county at an average of 80 feet above the Uniontown coal in the relative position of the Waynesburg coal; this could be considered the upper boundary of the Monongahela. However, because of the confusion which can occur in the identification of this and other smuts of the group and because of the lack of continuity of the smut in some areas, the Monongahela Group is not mapped as a unit. The Pittsburgh, Uniontown, and Washington coals are readily delineated where they are present in the county (pl. 1), and the sequences from the Pittsburgh coal to the Uniontown coal (Pittsburgh formation of Berryhill and Swanson, 1962, p. C45) and from the Uniontown coal to the Washington coal (Uniontown and Waynesburg formations of Berryhill and Swanson, 1962, p. C45) are more definable units.

Twenty-two units have been previously identified in the Monongahela of Ohio (Stout and others, 1943). These are, in ascending order: (1) Pittsburgh (No. 8) coal, (2) Upper Pittsburgh sandstone, (3) Redstone limestone, (4) Redstone (Pomeroy) coal, (5) Pomeroy sandstone, (6) Fishpot limestone, (7) Fishpot coal, (8) Lower Sewickley sandstone, (9) Meigs Creek (No. 9) (Sewickley) coal, (10) Upper Sewickley sandstone, (11) Benwood limestone, (12) Fulton shale, (13) Arnoldsburg limestone, (14) Arnoldsburg coal, (15) Arnoldsburg sandstone, (16) Uniontown limestone, (17) Uniontown (No. 10) coal, (18) Uniontown shale and sandstone, (19) Waynesburg limestone, (20) Little Waynesburg coal, (21) Gilboy shale and sandstone, and (22) Waynesburg (No. 11) coal.

Only those units which were identified in Washington County are discussed.

## DESCRIPTION OF UNITS

### Pittsburgh (No. 8) coal

The Pittsburgh coal, which was named by Rogers (1839, p. 96-97), marks the base of the Monongahela Group and is widely recognized in the county where due on the crop (pl. 1). There has been, however, some controversy over the identification of the unit in this general area. Stout (1954, v. II, p. 31) stated:

> A coal closely allied to the Pittsburgh coal, and often mistaken for it, is present with fair development in a small field along Duck Creek and its tributary, East Fork, and along Pawpaw Creek across Salem Township. This coal is probably the Upper Little Pittsburgh, but for clarity until more is known about its stratigraphic relations over a wide area, it will be called the Lower Salem as this village is near the center of the known field. The member is thus near the top of the Conemaugh series. According to a number of accurate measurements its position varies from 10 to 22 feet below the Pittsburgh coal and averages close to 14 feet 7 inches.

An examination of the sections designated by Stout as containing both his Lower Salem coal and the Pittsburgh coal reveals no true coal at his Pittsburgh position. Several sections in north-central Salem Township do have a few inches of carbonaceous shale at or near the top of the upper pelecypod-bearing limestone; this would be the Pittsburgh coal of Stout. However, this zone is restricted to a small number of outcrops and does not in the opinion of the authors represent the Pittsburgh coal. For the purposes of this report the coal that is in Washington County termed by some observers the Lower Salem is here correlated with the Pittsburgh coal.

The Pittsburgh ranges from bright blocky coal of marginal mineable thickness to a fraction of an inch of carbonaceous clay or shale (fig. 5). The unit is restricted in outcrop to the major valleys in Salem, Aurelius, Lawrence, southern Liberty, and western Ludlow Townships and to the Newell Run anticline area of Newport Township (pl. 1). With the exception of a small deep occurrence of thick coal (up to 96 inches) extending from the Federal Creek field of Athens County into westernmost Decatur Township, the thickest Pittsburgh, as much as 36 inches, is found in Salem Township in the vicinity of Lower Salem. The unit thins rapidly to the north and west and in northern Aurelius Township is represented by only a very thin carbonaceous clay or shale (fig. 5). Data are sparse to the south and east of Salem Township, but it appears that the Pittsburgh may be on the order of 14 inches thick over much of Lawrence and Liberty Townships and that it grades into a carbonaceous clay or shale farther to the east and south.

The Pittsburgh coal in most of Washington County is underlain and overlain by the pelecypod-bearing Upper Pittsburgh and Redstone limestones, respectively. This relationship, not known to exist in the case of any other coal, has been known for many years. Andrews (1869, p. 129) mentioned the presence of "fossil mollusca" below the coal and at a later date (1874) cited the overlying limestone and shales as being fossiliferous, but did not specifically mention mollusks. Local inhabitants have long distinguished between the "limestone coal" (Pittsburgh) and the higher "sandstone coal" (Meigs Creek). Bownocker and others (1908, p. 65), speaking of the Pittsburgh coal in this region, stated that

> . . . the coal is known as the "Limestone" or "Lower Salem" because of the limestones associated with it and from its being mined near the village, Salem, where a higher seam, the Meigs Creek is also worked.

The interval between the Pittsburgh and the Meigs Creek increases slightly from northwest to southeast (pl. 2), but averages about 90 feet and is a good guide to the identification of both coals.

The following two sections show the character of the Pittsburgh and its relationship to the overlying and underlying limestones at representative points in the county:

O.G.S. 8820, Salem Twp., SE¼ of the NE¼ sec. 26, Lower Salem 7½- and Macksburg 15-minute quadrangles. Measured in stream and along hillside. Measured by G. Bell. Base elevation 743 feet.

| | ft | in | ft | in |
|---|---|---|---|---|
| *Units 26 through 43 omitted* | | | | |
| 25. Clay shale, gray to dark-gray; some limonite staining; abundant pelecypods; "upper | | | | |

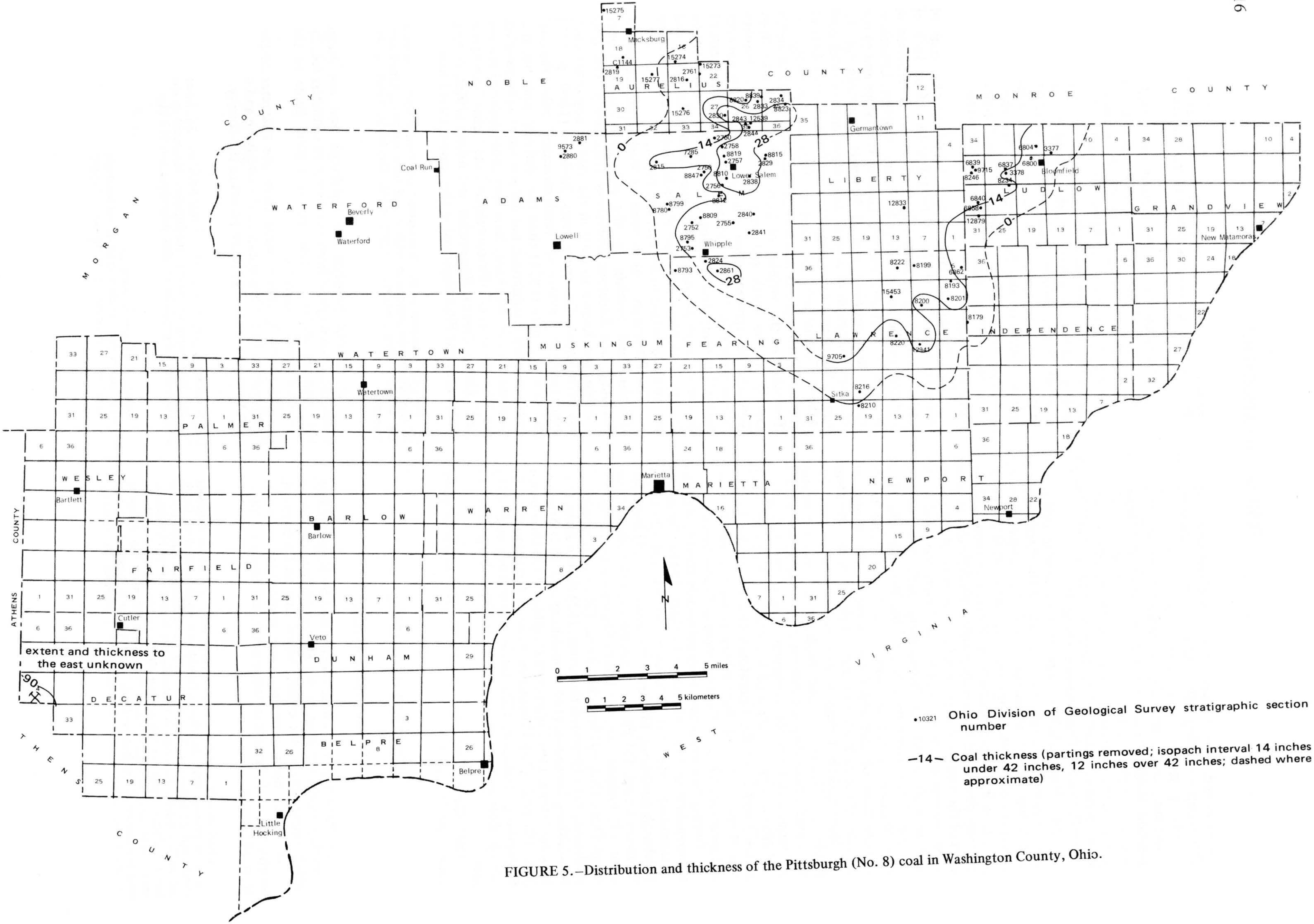


FIGURE 5.–Distribution and thickness of the Pittsburgh (No. 8) coal in Washington County, Ohio.

| | | | | |
|---|---|---|---|---|
| pelecypod zone" | 0 | 2 | 30 | 7 |
| 24. Clay shale, gray to bluish-gray, silty, calcareous; weathering soft; abundant ostracods | 0 | 6 | 30 | 5 |
| 23. Limestone, buff, semilithographic, very hard, massive; some ostracods | 0 | 2 | 29 | 11 |
| 22. Limestone, dark gray at base, becoming gray upward; argillaceous; somewhat banded; weathering platy; ostracods extremely abundant | 0 | 8 | 29 | 9 |
| 21. Limestone, buff, dense, hard; very irregular in thickness; congomeratic with rounded to angular gray limestone pebbles ranging up to 2 inches in diameter; desiccation conglomerate in part | 0 | 11 | 29 | 1 |
| 20. Covered | 2 | 0 | 28 | 2 |
| 19. Limestone, gray to dark-bluish-gray, dense; some pyrite; weathering a distinctive yellow brown | 0 | 9 | 26 | 2 |
| 18. Limestone, gray to bluish-gray, slightly argillaceous, hard, slightly conglomeratic; weathering rounded and pitted; ostracods and a few pelecypods(?) in the basal 2 inches | 1 | 0 | 25 | 5 |
| 17. Shale, bluish-gray, silty to clayey; with irregular gray limestone knots | 0 | 8 | 24 | 5 |
| 16. Covered | 0 | 6 | 23 | 9 |
| 15. Coal; blocky bright and dull coal bands, bony in the upper part; lying on the siltstone of unit 10 about 140 yards upstream, 2 feet 8 inches higher in elevation due to dip. PITTSBURGH | 1 | 0 | 23 | 3 |
| 14. Shale, carbonaceous, black, silty; some white mica; abundant coaly plant fragments | 1 | 0 | 22 | 3 |
| 13. Siltstone, black, very carbonaceous, micaceous, massive; few poorly preserved pelecypods | 0 | 4 | 21 | 3 |
| 12. Shale, dark-gray to dark-brown, silty, slightly micaceous, soft; some ostracods | 0 | 3 | 20 | 11 |
| 11. Limestone, dark-gray, argillaceous; weathering walnut brown and platy; well-preserved pelecypods and ostracods; "lower pelecypod zone" | 0 | 6 | 20 | 8 |
| 10. Siltstone, gray, micaceous; cross-bedded; weathering soft and shaly in part; some massive zones | 4 | 5 | 20 | 2 |
| 9. Shale, gray to bluish-gray, silty, micaceous; weathering soft; limonite concentrations along joints | 1 | 6 | 15 | 9 |
| *Units 1 through 8 omitted. Section modified slightly from original* | | | | |

O.G.S. 8199, Lawrence Twp., E½ of the NE¼ sec. 18, Dalzell 7½- and Macksburg 15-minute quadrangles. Measured along road from near section line southeastward to road junction at elevation 1041 feet. Measured by A. T. Cross and W. H. Smith. Base elevation 670 feet (estimated).

| | ft | in | ft | in |
|---|---|---|---|---|
| *Uppermost 329 feet 6 inches omitted* | | | | |
| Sandstone, greenish-brown to gray-green, medium to coarse-grained, highly micaceous; concealed above | 13 | 6 | 47 | 0 |
| Shale, variegated green to purple; weathering chippy | 8 | 10 | 33 | 6 |
| Limestone, gray, shaly, clayey | 0 | 6 | 24 | 8 |
| Shale, gray, calcareous, laminated | 0 | 3 | 24 | 2 |
| Limestone, gray, shaly; hard above | 1 | 7 | 23 | 11 |
| Limestone, dark, coaly, laminated; grading into hard limestone above; lower part fossiliferous, containing many small pelecypods | 1 | 0 | 22 | 4 |
| Limestone, gray, dense, hard, petroliferous | 1 | 2 | 21 | 4 |
| Limestone, gray; irregular in thickness; with soft shaly zones | 1 | 2 | 20 | 2 |
| Limestone, dolomitic; same as next below | 0 | 8 | 19 | 0 |
| Limestone, shaly; same as next below; ranging from 8 to 11 inches | 0 | 10 | 18 | 4 |
| Limestone, gray, dolomitic; weathering yellow | 0 | 11 | 17 | 6 |
| Limestone, gray-blue, shaly | 1 | 3 | 16 | 7 |
| Limestone, dove-gray, fossiliferous, petroliferous; ranging from 1 foot 2 inches to 2 feet | 1 | 9 | 15 | 4 |
| Shale, same as next shale below but less clayey; ranging from 1 foot 2 inches to 2 feet | 1 | 7 | 13 | 7 |
| Limestone, very dark, dense, hard | 1 | 0 | 12 | 0 |
| Shale, blue-gray, clayey; ranging from 1 foot 1 inch to 1 foot 8 inches (thinner over concretions below) | 1 | 6 | 11 | 0 |
| Coal, blocky; with some pyrite partings in lower part and thick resistant 7- to 12-inch concretions at top. PITTSBURGH | 1 | 5 | 9 | 6 |
| Shale, coaly, and coal, shaly | 0 | 10 | 8 | 1 |
| Clay shale, gray, coaly; with irregular nodular limestone above | 0 | 10 | 7 | 3 |
| Limestone, dark-gray, coaly; pelecypods at top | 0 | 8 | 6 | 5 |
| Clay shale, gray, calcareous, poorly exposed | 2 | 0 | 5 | 9 |
| Limestone, light-gray, and shale, dark, interbedded, calcareous; in several 6-inch beds | 2 | 3 | 3 | 9 |
| Limestone, gray, rubbly, nodular; calcareous shale matrix; lowest part concealed in stream | 1 | 6 | 1 | 6 |

The Pittsburgh coal in the county cannot be considered to have important economic potential, because of relatively low reserve tonnage and poor quality. A fuller discussion of the reserves, thickness, and chemical quality will be found in the mineral resources chapter. Descriptions of the coal are given in stratigraphic sections O.G.S. 15276 (p. 14), 8823 (p. 68), 6837 (p. 68), 8246 (p. 69), and 12539 (p. 69).

### Redstone limestone

The Redstone limestone, named by Platt and Platt (1877, p. 62) from exposures along Redstone Creek, Pennsylvania, is a reliable stratigraphic marker which is present over the Pittsburgh coal throughout most of the county. The unit ranges from 5 to 18 feet in thickness, but 10 to 12 feet is more common. It is represented by several beds of dense fossiliferous finely crystalline light- to dark-gray to black freshwater limestone with numerous interbeds of dark-gray mudstone or calcareous fossiliferous dark-gray shale. Stratigraphic sections O.G.S. 8199 (opposite) and 8820 (p. 15) illustrate the nature of the individual limestone beds and the relationship of the unit as a whole to the underlying Pittsburgh coal. In most of Aurelius and part of Adams Townships calcareous mudstone with limy nodules is found in the position of the Redstone.

Ostracods and pelecypods are abundant and in many localities the former form thin, almost coquinal, layers. Pelecypods may be as much as ¼ inch in length and are found most commonly as molds or casts. Fish remains, small gastropods, *Spirorbis,* and carbonized pieces of plant debris are found also in some abundance.

The threefold association of the pelecypod-bearing Redstone limestone, the underlying Pittsburgh coal, and the pelecypod-bearing Upper Pittsburgh limestone, constitutes a stratigraphic sequence that can be traced with relative ease throughout virtually all its outcrop area.

### Redstone (Pomeroy) coal

A thin smut in the position of the Redstone coal was recognized in a very few sections. However, smuts in this general position can easily be confused with the higher and far more persistent Fishpot coal smut, and correlation of these few occurrences with the Redstone is of doubtful validity.

### Fishpot limestone

The Fishpot limestone was named by Stevenson (1876, p. 67) from exposures on Fishpot Run in Washington

County, Pennsylvania. In Washington County, Ohio, this limestone is 3 feet thick or less or may be represented by calcareous mudstone. At many localities there is no bed representative of a carbonate environment present in this position.

The following section illustrates the nature of the rocks in the interval from the Fishpot limestone to the Meigs Creek coal:

O.G.S. 15266, Adams Twp., x = 2,277,100 feet, y = 574,400 feet, Lowell 7½- and Caldwell 15-minute quadrangles. Section begins at first ford on Bear Run approximately 1 mile south of the Noble-Washington County line. Measured by H. R. Collins and B. E. Smith. Base elevation 690 feet.

| | *ft* | *in* | *ft* | *in* |
|---|---|---|---|---|
| 8. Coal, thickness reported by owner. MEIGS CREEK | 4 | 0 | 43 | 10 |
| 7. Covered | 15 | 0 | 39 | 10 |
| 6. Sandstone, buff to dark-gray, fine- to medium-grained, massive to flaggy | 13 | 3 | 24 | 10 |
| 5. Shale, medium-gray, medium- to thick-bedded; limestone nodules abundant | 5 | 0 | 11 | 7 |
| 4. Clay shale, light- to medium-gray to green-gray; fair bedding below; poorly bedded upward; top ½ inch dark carbonaceous zone | 2 | 7 | 6 | 7 |
| 3. Shale, black, clayey, to coal, shaly, very carbonaceous, plastic | 0 | 4 | 4 | 0 |
| 2. Shale, dark-gray to black, carbonaceous, hard, compact. FISHPOT coal position(?) | 0 | 5 | 3 | 8 |
| 1. Limestone, medium-gray, finely crystalline, dense, hard, massive. FISHPOT | 3 | 3 | 3 | 3 |

Neither the Fishpot limestone nor the overlying smut representing the Fishpot coal are outstanding stratigraphic markers. There are other thin lime stringers and smuts which can be and are confused with the Fishpot limestone and smut and it is necessary to analyze the entire Meigs Creek-Pittsburgh interval before assigning identifications. In general, the identification of both units rests on recognition of either the underlying Pittsburgh or the overlying Meigs Creek coal.

### Fishpot coal

A rather persistent smut is present 40 to 50 feet above the Pittsburgh coal in the position of the Fishpot coal (pls. 2, 3, 4). The name Fishpot was proposed by Stout and used by Lamborn (1930, p. 233). Although generally quite thin, the smut is found in most of the stratigraphic sections exposing the rocks between the Pittsburgh and Meigs Creek coals.

The unit ranges from a carbonaceous dark-gray clay or shale to thin blocky coal or coaly shale (see O.G.S. 15266, above). Thicknesses of 6 inches or less are representative for this unit.

### Lower Sewickley sandstone

Sandstone, shale, or interbedded sandstone and shale occupy most of the interval between the Fishpot and the Meigs Creek coal beds (pls. 2, 3; O.G.S. 15266, above). Sandstones in this position in West Virginia have been named the Lower Sewickley by Hennen (1912, p. 201). Sand bodies in the Lower Sewickley position are rather widely distributed throughout Washington County. The thicker sandstones seem to be more common in Fearing, Lawrence, Ludlow, and Newport Townships. These sandstones measure from a few feet to over 40 feet in thickness, exhibit poor lateral continuity, are fine to medium grained, massive to shaly, and calcareous to noncalcareous.

### Meigs Creek (No. 9) (Sewickley) coal

The Meigs Creek coal was named by Brown (1884, p. 1059) for exposures along Meigs Creek in Morgan County, Ohio. The term Sewickley, as used by Rogers (1858), antedates the name Meigs Creek, but the latter is retained here because of its widespread use in the Ohio literature and among the state's coal producers.

Over most of Washington County the Meigs Creek (pls. 2, 3, 4) is separated into two distinct benches by a clay or shale parting. This parting is over 40 inches thick in a few places (see O.G.S. 15274, p. 70); however, 12 to 24 inches is more common. Generally, where the coal is thick, the parting is also thick. Where the coal and the main parting are thin, it is extremely difficult, if not impossible, to distinguish between the main parting and other thin partings which are normally present in both the upper and lower benches of the coal.

The Meigs Creek is commonly overlain by several feet of sandy light- to dark-gray shale with abundant plant compressions. The shale in turn is overlain by massive Sewickley sandstone (pls. 2, 3, 4). Local residents have long called the Meigs Creek the "sandstone coal" because of this massive overlying sandstone, which is absent in all or parts of Adams, Aurelius, Independence, Ludlow, Muskingum, Newport, Waterford, and Wesley Townships. In these townships limestones and shales of the Benwood-Uniontown sequence overlie the coal (fig. 7, pls. 2, 3, 4).

The Meigs Creek is the most important coal in the county, being found in mineable thickness in parts of Adams, Aurelius, Decatur, Independence, Lawrence, Liberty, Ludlow, Newport, Salem, Waterford, and Wesley Townships. Figure 6 shows the distribution and reserve thickness of this unit in the county. The unit is easily traced laterally from the areas of thick bright blocky coal to a very thin carbonaceous clay, which is believed to mark the limits of the swamp in which the coal was formed. Little or no indication of the Meigs Creek coal was found in examination of several sets of well samples in the area beyond the zero thickness line. Oil-well drillers rather consistently report the absence of coal south and west of the Muskingum River.

### Sewickley sandstone

The term Sewickley was used by White (1891, p. 60) for the sandstones lying over the Sewickley coal and under the Benwood limestone. The term Upper Sewickley has been applied by Hennen (1912, p. 199-200) to sandstones in this position.

The Sewickley is a friable cross-bedded massive medium- to coarse-grained sandstone present as a long northwest-trending body extending from eastern Newport through Aurelius Township and into Noble County on the north. The thickness of the sand body differs from place to place, but 50 feet or more is not uncommon along the main axis (fig. 7, pls., 2, 3, 4), where the sandstone appears to have been deposited at least in part in a channel which had been cut down to, and in some cases through, the Meigs Creek coal. Channeling to this depth does not appear to have been widespread, however. The Sewickley has good north-south continuity and can be traced with relative ease along this axis.

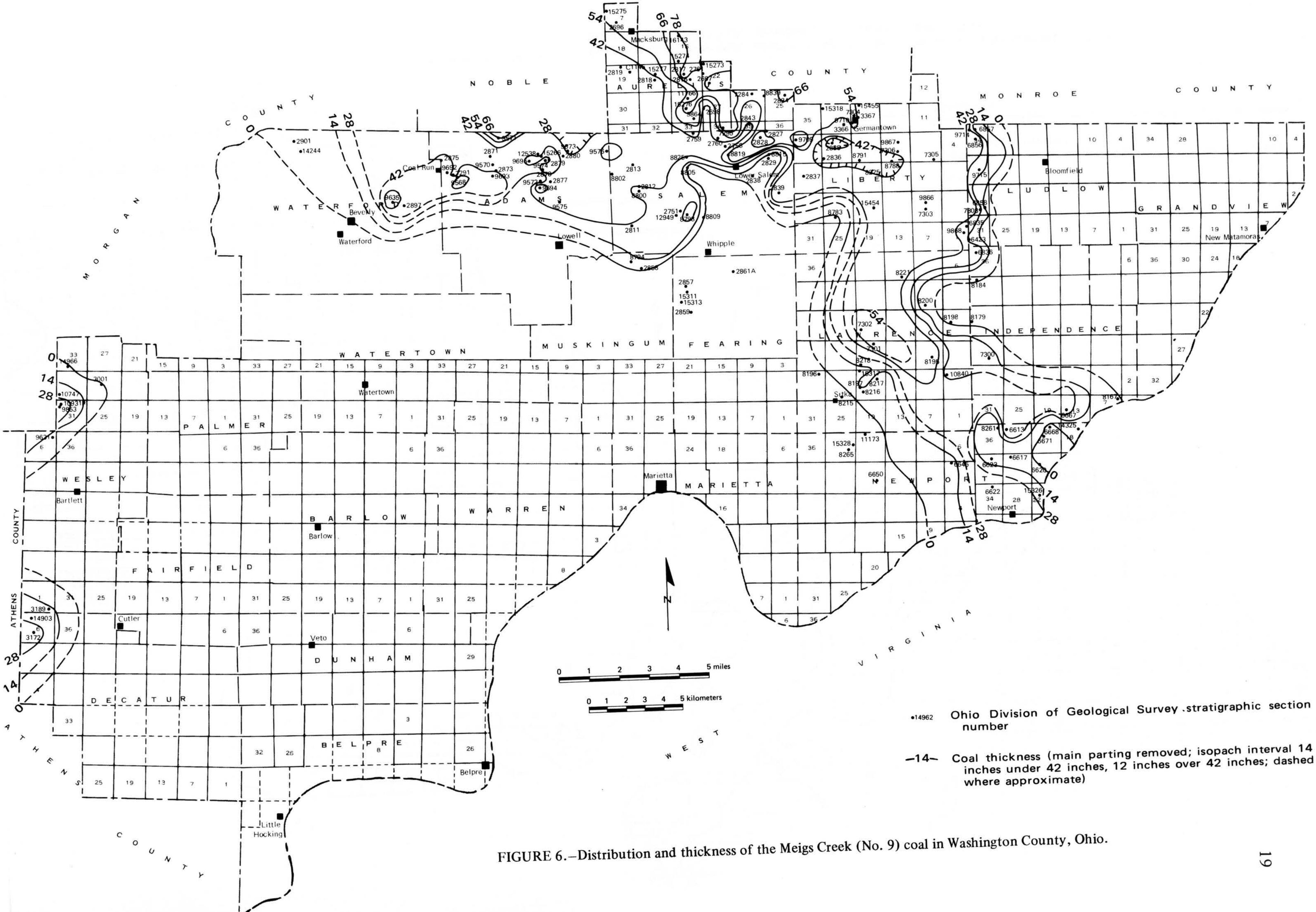


FIGURE 6.–Distribution and thickness of the Meigs Creek (No. 9) coal in Washington County, Ohio.

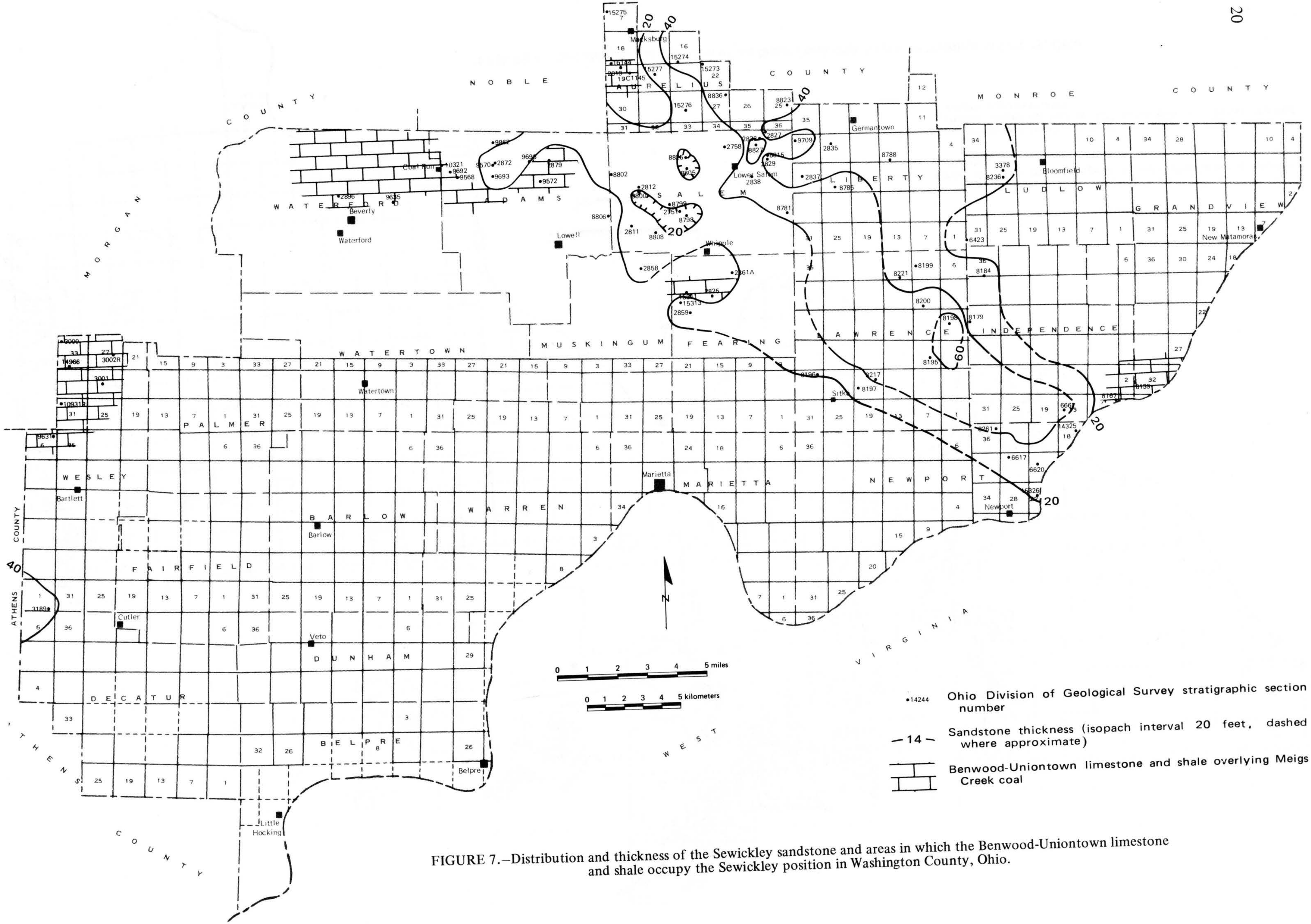


FIGURE 7.–Distribution and thickness of the Sewickley sandstone and areas in which the Benwood-Uniontown limestone and shale occupy the Sewickley position in Washington County, Ohio.

The unit thins and disappears to both the east and west away from the central axis of the main sand body. Limestone and shale of the Benwood-Uniontown sequence occupy the position of the sandstone on both the east and west sides of the channel (fig. 7; pls. 2, 3, 4). Interfingering of the sand body with the Benwood-Uniontown sequence is suspected, but very little direct evidence was found.

### Benwood limestone through Uniontown limestone

In Washington County the interval from the Sewickley sandstone to the Uniontown coal, and in some cases from the Meigs Creek coal to the Uniontown coal, is occupied by a thick sequence of limestones, calcareous shales, calcareous mudstones, and thin calcareous sandstones that is the equivalent of the Benwood of Campbell (1903, p. 10). This sequence consists of Benwood limestone, Fulton shale, Arnoldsburg limestone, Arnoldsburg coal, Arnoldsburg sandstone, and Uniontown limestone of east-central Ohio; in Washington County these beds are essentially indistinguishable as discrete units. Stout (1954, v. 2, p. 196) indicated that these units have poor definition also in Athens, Gallia, Lawrence, Meigs, Morgan, Muskingum, and Washington Counties:

> ... the interval from the Meigs Creek coal to the Uniontown coal is largely made up of a succession of strata, calcareous shales and irregularly bedded limestones, freshwater in origin. The proportion of shale to limestone varies both laterally and vertically from place to place, but the section as a whole shows much similarity throughout the field. This section must be treated as a unit or as separate members through indefinite breaks. The Fulton green shale of eastern Ohio is not present in the area; the Arnoldsburg coal is absent or very uncertainly represented; and the Arnoldsburg sandstone is lacking in continuity and variable in thickness and character. Under such conditions the Benwood and Arnoldsburg limestones of eastern Ohio are merged into one physical unit, and in large areas the overlying Uniontown limestone coalesces with the underlying Arnoldsburg limestone, showing no demarcation.

The Benwood-Uniontown sequence in the report area ranges in thickness from about 35 feet where the Sewickley sandstone is thick to slightly over 100 feet where the lowest beds of the sequence rest on the Meigs Creek coal or on thin Sewickley sandstone (pls. 2, 3, 4). Where the sequence consists of limestone, individual beds normally are on the order of 1½ feet thick and generally do not exceed 3 feet in thickness. In places several beds of limestone with very thin shaly partings aggregate 12 to 15 feet of fairly good limestone (see limestone discussion, mineral resources chapter).

Nonbedded or poorly bedded varicolored calcareous mudstones make up the major portion of the sequence in many places. Thin beds of rubbly or nodular limestone are commonly interbedded with the mudstones, and lenses of calcareous argillaceous fine-grained sandstones several feet thick are found irregularly through the sequence. The sandstones exhibit very poor lateral continuity. Slumping of the incompetent mudstone portions of the unit is responsible for a lack of good sections, a situation which adds materially to the problems of subdividing this rather complex sequence.

A smut only a fraction of an inch thick has been recognized about 25 feet below the Uniontown coal in a very few sections in the eastern half of the county and could be the equivalent of the Arnoldsburg coal. A smut which can be confused in the field with the Uniontown is found in the same relative position in the westernmost portion of the county, particularly in central and southern Waterford Township.

The following sections show the general character of the Benwood-Uniontown sequence at widely separated localities throughout the county:

O.G.S. 8184, Independence Twp., S½ sec. 36, Rinard Mills 7½- and New Matamoras 15-minute quadrangles. Measured along abandoned road going downhill along the section line between 35 and 36. Measured by A. T. Cross and W. H. Smith. Base elevation 692 feet.

| | ft | in | ft | in |
|---|---|---|---|---|
| *Uppermost 147 feet 5 inches omitted* | | | | |
| Coal, shaly; somewhat slumped | 0 | 2 | 127 | 7 |
| Clay shale, gray | 0 | 4 | 127 | 5 |
| Coal, shaly | 0 | 1 | 127 | 1 |
| Clay shale, gray | 0 | 4 | 127 | 0 |
| Coal, blocky to shaly; somewhat silty in zones; bony and platy toward top; considerably weathered. UNIONTOWN | 0 | 10 | 126 | 8 |
| Siltstone, coaly; leached limestone zone | 0 | 2 | 125 | 10 |
| Clay shale | 0 | 2 | 125 | 8 |
| Siltstone, coaly, laminated; interbedded with thin shale | 1 | 8 | 125 | 6 |
| Shale, gray; considerable yellow iron stain; one coaly shale 10 inches above base and coaly siltstone 6 inches below top | 2 | 0 | 123 | 10 |
| Shale, coaly, and coaly rash | 0 | 2 | 121 | 10 |
| Limestone, gray, dense, lithographic, fossiliferous (slightly); in two beds | 1 | 5 | 121 | 8 |
| Shale, with considerable pyrite; coaly rash | 0 | 4 | 120 | 3 |
| Shale, gray-green to tan; calcareous with irregular bedding | 6 | 11 | 119 | 11 |
| Shale, gray to purple, calcareous, poorly exposed; coaly shale at top with fossiliferous limestone blocks weathering out | 0 | 9 | 113 | 0 |
| Siltstone, green, hard, siliceous; almost a limestone | 1 | 4 | 112 | 3 |
| Limestone, gray, silty; weathering white; laminated weathered surface | 0 | 10 | 110 | 11 |
| Shale, dark-purple, poorly exposed | 1 | 1 | 110 | 1 |
| Limestone, gray, fossiliferous; cut by solution | 1 | 0 | 109 | 0 |
| Shale, marly same as next lower shale bed but with fewer limestone knots; color changing to olive green in uppermost 7 feet. | 12 | 0 | 108 | 0 |
| Limestone, white to purple, marly, rubbly, conglomeratic | 2 | 0 | 96 | 0 |
| Shale, marly, and limestone, reddish-purple to mottled green and purple; abundant small 1- to 4-inch white limestone knots weathering out; poorly exposed | 8 | 6 | 94 | 0 |
| Shale, purple and blue-green, mottled, marly, highly calcareous | 8 | 6 | 85 | 6 |
| Concealed; greenish-brown sandstone blocks weathering out | 4 | 3 | 77 | 0 |
| Limestone, red, marly; shale, marly; white limestone knots partially concealed in zones | 9 | 1 | 72 | 9 |
| Limestone, white and nodular to gray-green and clayey | 0 | 8 | 63 | 8 |
| Limestone, green, hard, sandy | 1 | 0 | 63 | 0 |
| Sandstone, gray to green, coarse- to fine-grained, thin-bedded, micaceous; transitional from sandstone below to limestone above | 1 | 8 | 62 | 0 |
| Sandstone, gray, massive, coarse-grained, poorly consolidated; micaceous with abundant black mica | 23 | 8 | 60 | 4 |
| Clay shale, gray, poorly exposed | 0 | 8 | 36 | 8 |
| Coaly shale, weathered, poorly exposed. MEIGS CREEK coal horizon | 0 | 6 | 36 | 0 |
| *Lowermost 35 feet 6 inches omitted* | | | | |

O.G.S. 8815, Salem Twp., x = 2,316,900 feet, y = 573,000 feet, Lower Salem and Dalzell 7½- and Macksburg 15-minute quadrangles. Measured up road about 1.1 miles northeast of Lower Salem to road junction at elevation 1003 feet, thence north about 0.15 mile to high point of road at top of hill. Measured by G. Bell. Base elevation 702 feet (barometer).

| | | ft | in | ft | in |
|---|---|---|---|---|---|
| | *Units 73 through 101 omitted* | | | | |
| 72. | Clay shale, dark-reddish-brown; top not exposed | 4 | 0 | 217 | 10 |
| 71. | Clay shale, dark-gray and carbonaceous at base; becoming medium gray upward; plastic where weathered | 0 | 2 | 213 | 10 |
| 70. | Limestone, olive-drab, very argillaceous, highly weathered; weathering to a clay shale; ranging up to 1 foot, with some interbedded red clay shale | 0 | 4½ | 213 | 8 |
| | UNIONTOWN coal zone | | | | |
| 69. | Clay, light-gray, plastic; several black carbonaceous streaks | 0 | 2 | 213 | 3½ |
| 68. | Marl, white, soft, slightly plastic | 0 | ½ | 213 | 1½ |
| 67. | Limestone, greenish-brown, siliceous, very argillaceous, shaly | 0 | 6 | 213 | 1 |
| 66. | Clay shale, light-grayish-brown; dark, very carbonaceous streak at top | 0 | 4 | 212 | 7 |
| 65. | Coal, shaly, weathered | 0 | 1 | 212 | 3 |
| 64. | Clay shale, olive-drab, calcareous | 0 | 4 | 212 | 2 |
| 63. | Clay shale, brownish-green, clayey to silty, slightly micaceous, calcareous | 2 | 0 | 211 | 10 |
| 62. | Limestone, buff, dense, hard; ostracods fairly abundant | 0 | 10 | 209 | 10 |
| 61. | Limestone, greenish-gray, very argillaceous, somewhat conglomeratic, very soft and shaly | 1 | 0 | 209 | 0 |
| 60. | Shale, like unit 58 | 0 | 6 | 208 | 0 |
| 59. | Limestone, buff, dense; conglomeratic in the upper part with subrounded to angular fragments of buff to dark-reddish-brown limestone set in a matrix of argillaceous greenish-gray limestone | 1 | 6 | 207 | 6 |
| 58. | Shale, variegated dark-reddish-brown, brown, and gray, silty, very calcareous; some purplish tints; abundant nodules, up to 6 inches, of variegated argillaceous limestone | 3 | 9 | 206 | 0 |
| 57. | Shale and shaly siltstone, light-brownish-green, slightly calcareous, slightly micaceous; some greenish-gray dense limestone nodules in the uppermost 2 inches | 4 | 0 | 202 | 3 |
| 56. | Limestone, dark-bluish-gray, argillaceous, very hard, nodular; very fossiliferous with gastropods, ostracods, and fish teeth | 0 | 8 | 198 | 3 |
| 55. | Clay shale, light-olive-gray, clayey to silty, marly; abundant small ⅛-inch gray argillaceous limestone nodules throughout | 3 | 3 | 197 | 7 |
| 54. | Shale and clay shale, variegated dark-reddish-brown, pink, gray, and brown, clayey to silty, very calcareous; some parts with a purplish tint; very abundant small nodules of gray to pink argillaceous limestone averaging ¼ inch in diameter | 23 | 2 | 194 | 4 |
| 53. | Covered; apparently red shale, probably like unit above | 10 | 4 | 171 | 2 |
| 52. | Shale, yellow-brown, sandy, micaceous | 6 | 10 | 160 | 10 |
| 51. | Sandstone, gray to brown, fine- to coarse-grained poorly sorted, very friable; grains rounded to subangular; much clayey material around the quartz grains; massive, with some thin bedded; some crossbedding. SEWICKLEY | 54 | 3 | 154 | 0 |
| 50. | Coal, highly weathered | 0 | 6 | 99 | 9 |
| 49. | Clay shale, dark-gray to brown; limonite concentrations at base | 0 | 6 | 99 | 3 |
| 48. | Coal, highly weathered, poorly exposed. MEIGS CREEK | 0 | 6 | 98 | 9 |
| | *Units 1 through 47 omitted* | | | | |

O.G.S. 14244, Waterford Twp., x = 2,235,200 feet, y = 577,950 feet, Beverly 7½- and Caldwell 15-minute quadrangles. Measured along Texas Eastern pipeline ditch uphill from Ohio Rte. 76 and Muskingum River crossing, about 0.3 mile east of mouth of Olive Green Creek. Measured by G. H. Denton and B. D. Middleton. Base elevation 740 feet (estimated, topographic map).

| | ft | in | ft | in |
|---|---|---|---|---|
| *Uppermost 119 feet 8 inches omitted* | | | | |
| Shale, dark-gray to black, carbonaceous, platy. UNIONTOWN coal zone | 1 | 6 | 115 | 11 |
| Shale, olive-green, clayey, crumbly, limy | 5 | 6 | 114 | 5 |
| Shale, dusky-red, orange-mottled, yellow and purple, clayey, crumbly | 5 | 4 | 108 | 11 |
| Shale, green-gray, somewhat platy | 0 | 1½ | 103 | 7 |
| Clay streak, soft, plastic | 0 | ½ | 103 | 5½ |
| Clay shale, light-green-gray | 0 | 2 | 103 | 5 |
| Siltstone, limy, to silty limestone; both dark-green to green-gray | 2 | 10 | 103 | 3 |
| Clay shale, purplish-red, limy, crumbly, nonbedded; scattered limestone knots and nodules | 15 | 0 | 100 | 5 |
| Clay shale, olive-green to yellow-green, limy, crumbly | 3 | 0 | 85 | 5 |
| Siltstone, shaly, olive-green, red- and yellow-mottled, finely micaceous; grading into overlying and underlying units | 11 | 6 | 82 | 5 |
| Shale, olive-green and dusky-red interbedded, silty, limy; lowermost portion partly slumped | 11 | 0 | 70 | 11 |
| Limestone, same as below, somewhat less pure | 2 | 10 | 59 | 11 |
| Siltstone to limestone as below | 1 | 1 | 57 | 1 |
| Limestone, same as next below | 0 | 11 | 56 | 0 |
| Siltstone, limy to shaly, highly calcareous, almost to limestone | 1 | 6 | 55 | 1 |
| Limestone, same as below | 0 | 10 | 53 | 7 |
| Siltstone, olive-green, limy to shaly | 1 | 2 | 52 | 9 |
| Limestone, massive, same as below | 2 | 10 | 51 | 7 |
| Shale, same as below | 0 | 3 | 48 | 9 |
| Limestone, same as below | 1 | 3 | 48 | 6 |
| Shale, medium-gray, limy (parting in limestone) | 0 | 4 | 47 | 3 |
| Limestone, medium-gray, massive, pure; weathering yellow | 3 | 9 | 46 | 11 |
| Clay shale, olive-green, mottled-red | 0 | 10 | 43 | 2 |
| Limestone, medium- to light-gray, pure, hard, weathering yellow | 3 | 4 | 42 | 4 |
| Clay shale, light-gray to greenish-gray, soft, calcareous | 4 | 10 | 39 | 0 |
| Limestone zone, medium-gray; weathering yellow; massive limestone interbedded with limy clay shale | 7 | 6 | 34 | 2 |
| Shale, olive-green and dusky-red interbedded; limestone nodules | 7 | 3 | 26 | 8 |
| Limestone, light-gray, fairly pure, nodular, hard; weathering yellow | 1 | 0 | 19 | 5 |
| Shale, dusky-red, crumbly, clayey, nonbedded | 7 | 4 | 18 | 5 |
| Limestone, impure, irregular, nodular; weathering yellow | 0 | 10 | 11 | 1 |
| Shale, yellow-gray to greenish-gray, soft; some red mottling | 2 | 6 | 10 | 3 |
| Shale, olive-green, soft, clayey, bedded; grading into unit above | 2 | 5 | 7 | 9 |
| Coal, irregular, smutty, highly weathered. MEIGS CREEK | 0 | 4 | 5 | 4 |
| Clay shale, olive-green; some silty zones; mottled dusky red | 5 | 0 | 5 | 0 |

## Uniontown (No. 10) coal

The Uniontown coal, named by Rogers (1858, p. 506) from exposures at Uniontown, Pennsylvania, is one of the most persistent stratigraphic elements in Washington County (fig. 8, pls. 2, 3, 4), outcropping throughout the county except where it is carried below drainage by the Parkersburg-Lorain syncline. The coal ranges from a few inches of carbonaceous shale or clay to a zone of alternating shale, clay, and bright blocky coal a few feet thick. A distinguishing characteristic of the unit in much of the area except the westernmost townships is a thin limestone parting (O.G.S. 8815, 15267).

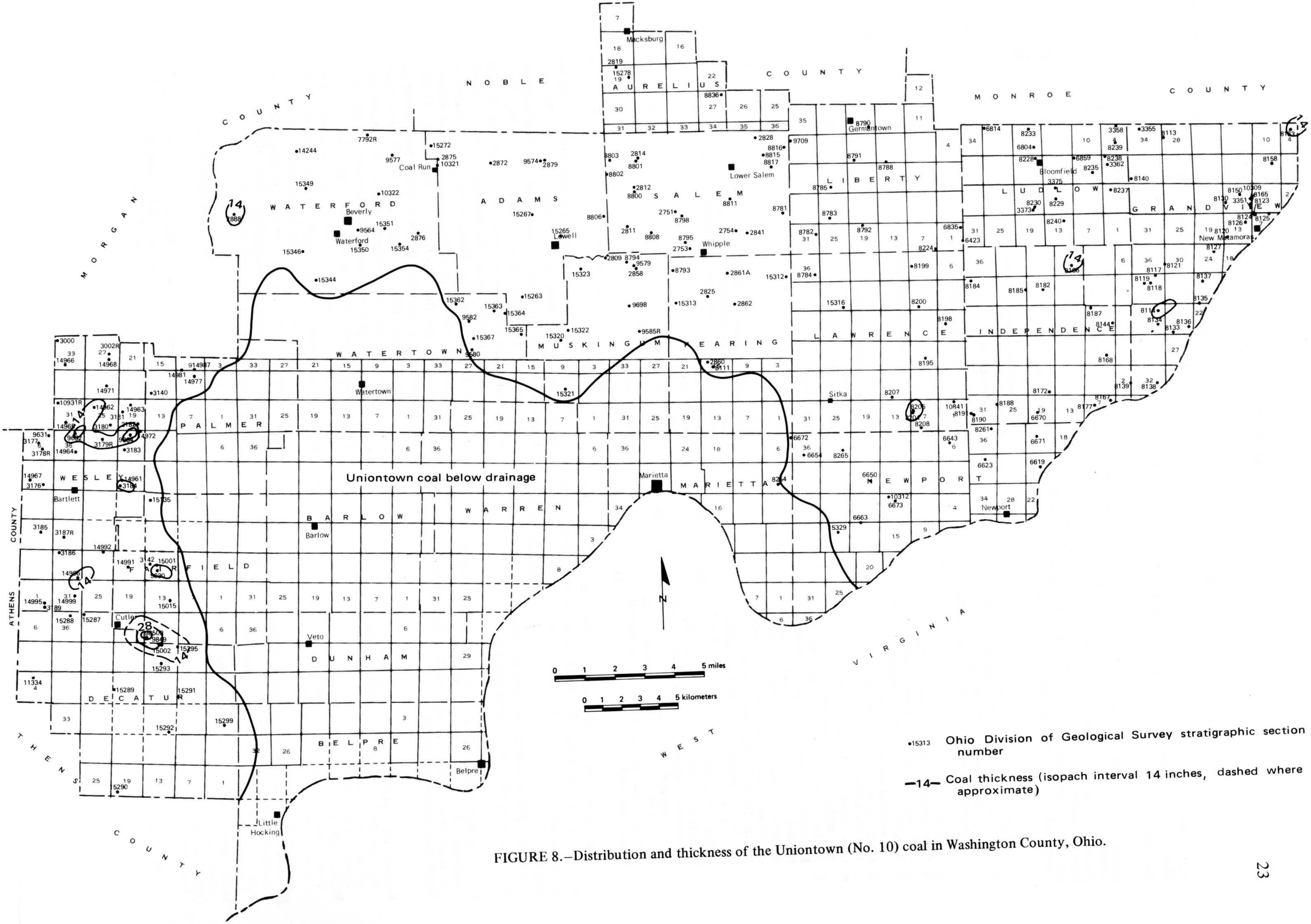


FIGURE 8.–Distribution and thickness of the Uniontown (No. 10) coal in Washington County, Ohio.

The thickest bright blocky coal is found in the westernmost part of the county, whereas the thickest coaly zones are found in the east. The following partial sections illustrate the limestone parting and the general character of the bed:

O.G.S. 15267, Adams Twp., x = 2,275,900 feet, y = 564,700 feet, Lowell 7½- and Beverly 15-minute quadrangles. Measured from stream level on second tributary to Cat Creek, one mile northwest of Lowell, starting where stream crosses road and following up stream and road to near top of hill on Twp. Rd. 153. Measured by H. R. Collins and B. E. Smith. Base elevation 640 feet.

| | *ft* | *in* | *ft* | *in* |
|---|---|---|---|---|
| *Units 11 through 20 omitted* | | | | |
| 10. Clay and covered; some light-gray clay, highly weathered and slumped, possibly representing another bench of coal in this unit | 2 | 2 | 94 | 5 |
| 9. Coal, blocky, bright to bony, weathered | 1 | 0 | 92 | 3 |
| 8. Clay, light-gray, plastic; stained yellow | 0 | 1 | 91 | 3 |
| 7. Coal, highly weathered, bony, sooty | 0 | 1 | 91 | 2 |
| 6. Limestone, dark-gray, dense, bedded; ostracods abundant; fish plates | 0 | 1 | 91 | 1 |
| 5. Coal, bony, sooty, highly weathered. UNIONTOWN | 0 | 2 | 91 | 0 |
| 4. Clay shale, olive-drab, nonbedded, hard, very slightly calcareous, sandy | 2 | 5 | 90 | 10 |
| 3. Shale and limestone interbedded. Limestone, medium-gray, argillaceous, bedded (beds 3 to 4 feet thick); desiccation breccia. Shale purple, red, dark-gray, calcareous; abundant limestone nodules; middle 15 or 20 feet very poorly exposed, top 30 feet exposed, top with abundant 2- to 3-foot limestone beds. BENWOOD-UNIONTOWN | 62 | 0 | 88 | 5 |
| 2. Mudstone, red, green, olive-drab, nonbedded, calcareous, sandy; contact with underlying sandstone covered | 1 | 9 | 26 | 5 |
| 1. Sandstone, olive-green, medium- to coarse-grained, massive to platy; cutting out Meigs Creek coal | 24 | 8 | 24 | 8 |

Uniontown coal of mineable thickness is restricted essentially to Decatur, Fairfield, and Wesley Townships. A discussion of the coal reserves and the economic potential of this unit is presented in the chapter on mineral resources. The following section illustrates the nature of the unit in one of the few areas of thick coal:

O.G.S. 14964, Wesley Twp., SE¼ sec. 36, Chesterhill 7½- and Chesterhill 15-minute quadrangles. Measured in Hutchison strip mine 1.5 miles north of Bartlett on Ohio Rte. 555. Measured by B. E. Smith. Base elevation 780 feet.

| | *ft* | *in* | *ft* | *in* |
|---|---|---|---|---|
| Sandstone, light-tan to brownish-tan, iron-stained, massive, medium-grained, micaceous; subrounded grains; badly weathered to dark brown | 3 | 0 | 40 | 1 |
| Shale, olive-gray to light-gray, red-mottled, iron-stained, clayey, silty; somewhat sandy in lowest portion; calcareous limestone nodules scattered throughout | 13 | 0 | 37 | 1 |
| Sandstone, drab to buff, iron-stained, massive, fine-grained, finely micaceous | 8 | 9 | 24 | 1 |
| Shale, light-gray to yellow-brown, iron-stained, somewhat sandy, heavily bedded | 4 | 6 | 15 | 4 |
| Shale, light-gray, platy, clayey, somewhat sandy, plant-fossiliferous | 7 | 6 | 10 | 10 |
| Coal, blocky, bright, heavy banded; bony in lowest portion. UNIONTOWN | 3 | 4 | 3 | 4 |

The following detailed section, of the Uniontown coal only, illustrates the nature of the bed in eastern Washington County, where the Uniontown is found in many places as a coal zone several feet thick.

O.G.S. 8123, Grandview Twp., SW¼ sec. 8, New Matamoras 7½- and New Matamoras 15-minute quadrangles. Measured at secondary road intersection on section line 0.5 mile north of New Matamoras. Measured by A. T. Cross. Elevation at base of coal 695 feet.

| | *ft* | *in* | *ft* | *in* |
|---|---|---|---|---|
| Clay shale | 2 | 0 | 26 | 5 |
| Shale, coaly | 0 | 5 | 24 | 5 |
| Coal, shaly | 0 | 5 | 24 | 0 |
| Shale, with some coaly streaks | 1 | 6 | 23 | 7 |
| Coal, blocky to platy | 0 | 3½ | 22 | 1 |
| Coal, blocky, hard | 0 | 2 | 21 | 9½ |
| Coal, blocky to platy | 0 | 1½ | 21 | 7½ |
| Shale, black, carbonaceous to coaly | 0 | 2 | 21 | 6 |
| Coal, blocky to platy | 0 | 1½ | 21 | 4 |
| Coal, shaly | 0 | ½ | 21 | 2½ |
| Shale, gray | 1 | 6 | 21 | 2 |
| Clay shale, with two coaly streaks | 0 | 2 | 19 | 8 |
| Coal, blocky | 0 | 1½ | 19 | 6 |
| Coal, shaly | 0 | 2 | 19 | 4½ |
| Clay, gray, carbonaceous | 0 | 1½ | 19 | 2½ |
| Coal, blocky | 0 | ½ | 19 | 1 |
| Clay, carbonaceous | 0 | ½ | 19 | ½ |
| Coal, blocky | 0 | 2 | 19 | 0 |
| Shale, coaly | 0 | 1 | 18 | 10 |
| Coal, blocky | 0 | 2½ | 18 | 9 |
| Clay, gray | 0 | 1½ | 18 | 6½ |
| Coal, blocky | 0 | 3 | 18 | 5 |
| Shale, gray | 2 | 9 | 18 | 2 |
| Shale, carbonaceous, black | 0 | 2 | 15 | 5 |
| Shale, gray; with carbonaceous laminations and much yellow iron stain; outcrop much weathered | 5 | 7 | 15 | 3 |
| Shale, bony, platy | 0 | 3 | 9 | 8 |
| Shale, sandy, coaly | 0 | 2 | 9 | 5 |
| Coal, silty and shaly | 1 | 0 | 9 | 3 |
| Clay shale, coaly and silty | 0 | 2 | 8 | 3 |
| Coal, blocky | 0 | 5 | 8 | 1 |
| Shale, gray | 5 | 8 | 7 | 8 |
| Limestone, silty, concealed below | 2 | 0 | 2 | 0 |

The interval from the Meigs Creek coal to the Uniontown averages 105 feet, with a range of 82 to 126 feet. The interval between the Uniontown and the Washington coal averages 195 feet and ranges from 173 to 216 feet. The restricted range of these intervals is a major aid in mapping and correlating beds across the county. Generally speaking, the identification of the Uniontown coal is based on its relationship to the thick underlying Benwood-Uniontown sequence and on the intervals to the Meigs Creek and Washington coals. In a few places in the westernmost part of the county a thin smut is found 20 to 50 feet below the Uniontown and can be confused with it. The presence of 20 to 50 feet of predominantly calcareous mudstones, siltstones, and thin limy sandstones over this lower smut indicates that the top of the Benwood-Uniontown sequence and the Uniontown coal are higher in the section. Confusion is most likely to arise when the lower smut is found resting on a limestone immediately overlain by noncalcareous sand or shale, a sequence suggesting that the top of the Benwood-Uniontown has been reached.

### Uniontown coal to Washington coal

The approximately 195 feet of strata exposed in the county between the Uniontown and Washington coals (pls. 3, 4) include the position of the Waynesburg coal, which has long been considered to mark the classic Pennsylvanian-Permian boundary in eastern United States. This boundary has more recently been placed at the base of the Washington coal (Berryhill and Swanson, 1962, p. C43). In Ohio the interval includes also the following named units: Uniontown shale and sandstone, Waynesburg limestone, Little Waynesburg coal, Gilboy sandstone, Waynesburg coal, Cassville shale, Elm Grove limestone, Waynesburg sandstone, Waynesburg "A" coal, Mannington sandstone, and Little Washington coal.

None of the stratigraphic units in this sequence is persistent throughout the entire county. Smuts representing the coals have the widest areal distribution and sandstones the least. Shales, thin sandstones, and mudstones are important constituents in the section but, because of complex intertonguing, a tendency to slump and become covered, and a lack of distinctive lithologic characteristics, individual beds or even sequences of beds could not be identified with certainty over any appreciable area. However, the sandstones, with their relatively thicker beds, greater resistance to erosion, and ledge-forming properties, were more readily traceable than the shales and mudstones; only those traceable over some distance are discussed here. Except for a very few beds and lenses, limestone is notably absent from the section. In Washington County, the authors identified five coal smuts, three sandstones, and one limestone between the Uniontown and Washington coals.

Earlier workers in this area have identified the Little Waynesburg, Waynesburg, and Waynesburg "A" coals at one place or another. However, there was little consistency in the nomenclature applied in the field, even that used by a given worker. The five smuts that the authors were able to identify with some degree of consistency in restricted parts of the county are found approximately 20, 50, 80, 107, and 135 feet above the Uniontown coal. Isolated smuts at other than these five positions were found in only a very few sections and had no recognizable geographic or stratigraphic patterns.

None of the five smuts identified by the authors seems to correlate fully with the Little Waynesburg, Waynesburg, Waynesburg "A," or Little Washington coals, although such identifications have been made by other workers. An erroneous identification of the Waynesburg coal in Liberty Township by White (1891, p. 29) was based on the supposition that the Macksburg coal of early workers in Washington County was equivalent to the Waynesburg. However, the Macksburg coal as used by early Ohio geologists and identified as Waynesburg in the section given by White is undoubtedly the Meigs Creek coal. The coal identified by White as the Washington "A" is in the approximate position of the Little Waynesburg coal of the present report.

The authors' correlations of the individual smuts were based on stratigraphic sequences, locally persistent lithologies, and intervals in all available sections for the Uniontown-Washington coal sequence. In local areas a smut occurring at a rather uniform stratigraphic interval intermediate to the previously mentioned average intervals may represent a discrete depositional pod and have no recognizable correlative in the adjacent area.

The correlation of these smuts is extremely tenuous, but does offer some basis for establishing a stratigraphic framework in this rather complex sequence of rocks.

### Uniontown shale and sandstone

The rocks overlying the Uniontown coal are normally shale and sandstone. White (1891, p. 58-59) used the term Uniontown for sandstone occupying this position. The thickness of this unit in Washington County is generally not over 25 feet, and only two thicknesses greater than 40 feet are recorded in the county. Seventy- two feet of sandstone is present in sec. 23, Independence Township (O.G.S. 8182), and approximately 63 feet is recorded in sec. 3, Grandview Township (O.G.S. 3349). Sandstones in this position are fine to medium grained (coarse grained in a few places), shaly to massively bedded, and commonly very calcareous. The shales are generally some shade of green and are silty to sandy. Stratigraphic position relative to the Uniontown coal is the greatest aid in identifying the sandstones and interbedded sandstones and shales of this unit.

### Unnamed coal smut

A very thin coal smut is found an average of 20 feet above the Uniontown coal in most of Decatur, southwestern Fairfield, northern Palmer, and central Wesley Townships. This position is generally represented by a few inches of light-gray clay with very thin streaks of carbonaceous material; only in a few places is coal present.

The unit has extremely limited distribution; of the five smuts between the Uniontown and Washington coals this unit is the most difficult to recognize and the least persistent; it is mentioned only because some workers have correlated it in the field with the Little Waynesburg coal.

### Waynesburg limestone

Thin limestone, limy shale, mudstone with lime nodules, or limy sandstone is found an average of 30 feet above the Uniontown coal in Fearing, Lawrence, Liberty, Muskingum, and Salem Townships. This is the only relatively persistent calcareous unit between the Uniontown and Washington coals and is most commonly a red mudstone as much as a few feet thick and bearing abundant limestone nodules. Very argillaceous limestone, generally less than 1 foot thick, is found at a few localities. This unit is tentatively correlated with the Waynesburg limestone.

The unit, although generally present in the central portion of the county, does not occur with the frequency or distinctive characteristics needed to make it a useful stratigraphic marker.

### Little Waynesburg coal

A second coal smut, found an average of 50 feet above the Uniontown coal, has been identified by most field workers in western Washington County as the Waynesburg coal (pls. 2, 3, 4) and in eastern Washington County as the Little Waynesburg. The 50 feet of strata approximates the average thickness of rocks between the Uniontown and Waynesburg coals elsewhere in Ohio, but a somewhat persistent calcareous zone in the position of the Waynesburg limestone suggests correlation with the Little Waynesburg coal.

The unit is relatively widespread (fig. 9), but is generally identified with difficulty and only through study of a large

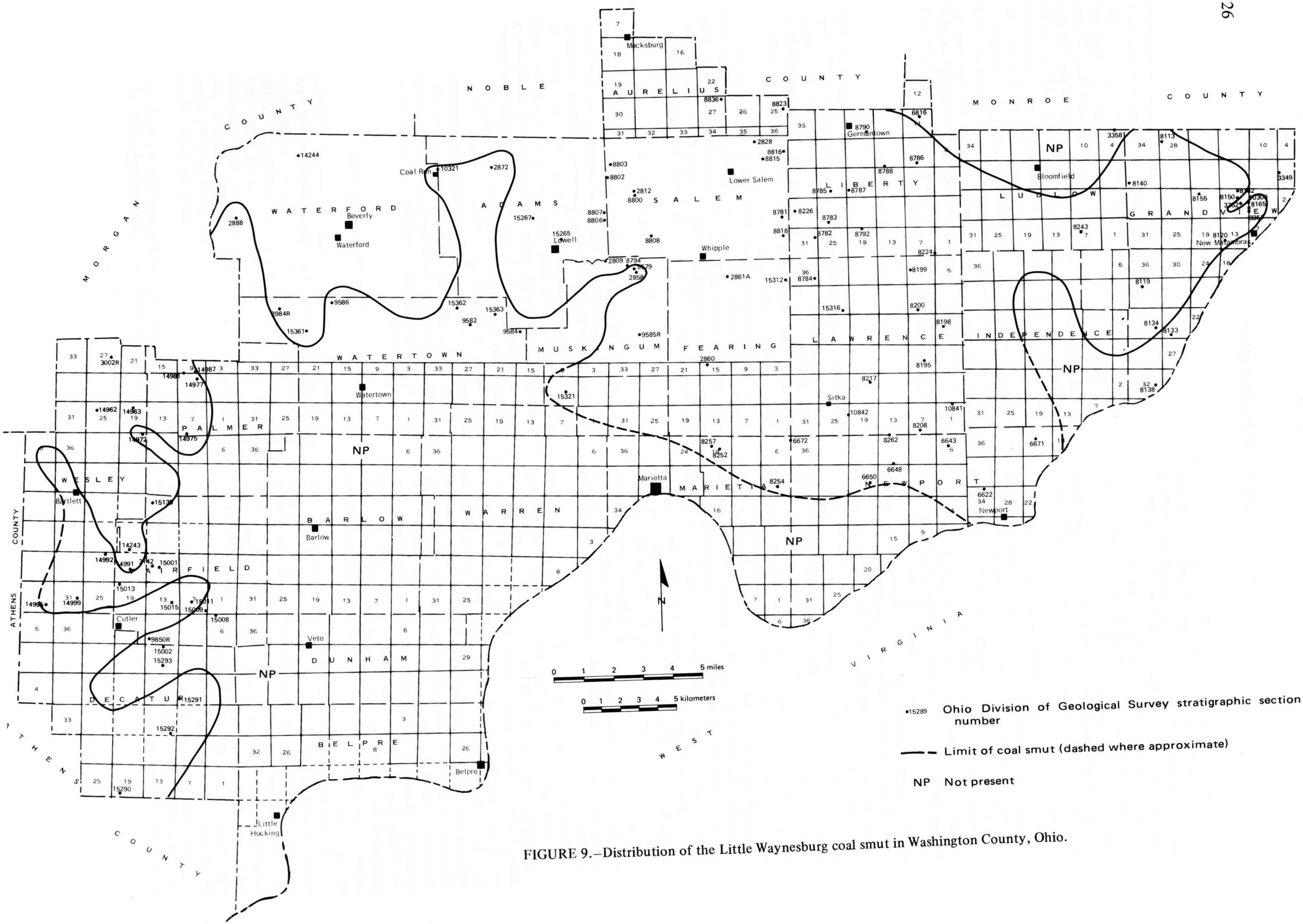


FIGURE 9.–Distribution of the Little Waynesburg coal smut in Washington County, Ohio.

number of sections covering the Uniontown-Washington sequence.

The unit ranges from an inch or so of carbonaceous clay to several inches of bony coal or alternating clay, carbonaceous shale, and coal. The following stratigraphic sections illustrate the nature of the unit at two widely spaced localities:

O.G.S. 15291, Decatur Twp., secs. 10 and 16, Cutler 7½- and Chesterhill 15-minute quadrangles. Measured starting at stream level on section line and going 200 yards east to Ohio Rte. 555 and then north up road to hilltop. Measured by H. R. Collins and B. E. Smith. Base elevation 620 feet (topographic map).

| | *ft* | *in* | *ft* | *in* |
|---|---|---|---|---|
| 17. Sandstone, yellowish-brown, iron-stained, massive, very coarse-grained; pothole weathering; honeycombed surface; case hardening of iron; pebbles of quartz in sandstone matrix; forming caves at base with large overhangs; top covered. HOCKINGPORT (WAYNESBURG) | 48 | 0 | 100 | 9 |
| 16. Clay, light-gray, nonbedded, plastic; top obscure to base of sandstone above | 1 | 6 | 52 | 9 |
| 15. Coal smut, nonbedded, highly weathered, shaly; dark carbonaceous clay with flecks of fusain | 0 | 2 | 51 | 3 |
| 14. Clay, light-gray, iron-stained, nonbedded, plastic | 0 | 7 | 51 | 1 |
| 13. Coal, shaly to clayey; fusain abundant | 0 | 6 | 50 | 6 |
| 12. Clay parting, light-gray, nonbedded, plastic, iron-stained | 0 | 6 | 50 | 0 |
| 11. Coal, some bright, shaly; 2-inch clay parting 3 inches up from base. LITTLE WAYNESBURG(?) | 0 | 8 | 49 | 6 |
| 10. Clay, light-gray, nonbedded, plastic | 2 | 11 | 48 | 10 |
| 9. Sandstone, olive-drab, thin-bedded, fine-grained, finely micaceous | 2 | 3 | 45 | 11 |
| 8. Clay shale, olive-drab, nonbedded to pseudobedded, silty; weathering red, with some red shale throughout; irregular chips; alternating in places with 3- to 4-inch calcareous beds; scattered limestone nodules at top; top gradational with unit above | 6 | 10 | 43 | 8 |
| 7. Sandstone, greenish-gray, massive- to thin-bedded, fine-grained, slightly calcareous; gradational top | 5 | 4 | 36 | 10 |
| 6. Sandstone and covered | 26 | 8 | 31 | 6 |
| 5. Shale, olive-green, thin-bedded, very sandy; gradational upward | 2 | 0 | 4 | 10 |
| 4. Shale, dark, carbonaceous, poorly bedded; plant debris; gradational into overlying unit | 0 | 1 | 2 | 10 |
| 3. Clay shale, red, yellow-mottled, nonbedded, slickensided | 0 | 3 | 2 | 9 |
| 2. Coal zone, black, shaly, very clayey and very carbonaceous. UNIONTOWN | 0 | 2 | 2 | 6 |
| 1. Clay shale, medium-gray, nonbedded, calcareous; limestone nodules | 2 | 4 | 2 | 4 |

O.G.S. 15267, Adams Twp., x = 2,275,900 feet, y = 564,700 feet, Lowell 7½- and Caldwell 15-minute quadrangles. Measured starting at stream level on second tributary to Cat Creek 1 mile north of Lowell and going upstream on Twp. Rd. 153 to top of hill. Measured by H. R. Collins and B. E. Smith. Base elevation 640 feet.

| | *ft* | *in* | *ft* | *in* |
|---|---|---|---|---|
| 20. Shale and sandstone interbedded, olive-drab, thin-bedded; some sand lenses calcareous, some shale red and thin bedded, top covered | 15 | 0 | 189 | 9 |
| 19. Coal and covered (the WAYNESBURG coal should be here; abundant evidence was found but the coal could not be found in place; coal and clay were found by digging in ditch and road, and there appears to have been a small opening here; coal is at bottom of this covered interval) | 13 | 8 | 174 | 9 |
| 18. Clay shale, olive-drab, nonbedded, sandy; light gray upward | 5 | 4 | 161 | 1 |
| 17. Sandstone, olive-drab, fine-grained, shaly, weathered | 8 | 1 | 155 | 9 |
| 16. Clay, medium- to dark-gray, semiplastic; carbonaceous in part; thin-bedded where carbonaceous. LITTLE WAYNESBURG(?) | 0 | 2 | 147 | 8 |
| 15. Clay shale, medium-gray, sandy, nonbedded, calcareous; limestone nodules | 5 | 10 | 147 | 6 |
| 14. Covered | 25 | 8 | 141 | 8 |
| 13. Sandstone, olive-drab, fine-grained, massive to slabby; calcareous in places; top covered | 2 | 0 | 116 | 0 |
| 12. Shale, red to greenish-gray, thin-bedded, plant-fossiliferous; sandy upward; gradational contact with overlying sandstone | 8 | 11 | 114 | 0 |
| 11. Covered; interval containing a thin fine-grained slabby calcareous green sandstone near base (sandstone does not show well here but was seen laterally along valley over the coal) | 10 | 8 | 105 | 1 |
| 10. Clay and covered; some light-gray clay highly weathered and slumped; may be another bench of coal in this unit | 2 | 2 | 94 | 5 |
| 9. Coal, blocky, bright to bony, weathered; small abandoned mine here | 1 | 0 | 92 | 3 |
| 8. Clay, light-gray, plastic; stained yellow | 0 | 1 | 91 | 3 |
| 7. Coal, bony, sooty, highly weathered | 0 | 1 | 91 | 2 |
| 6. Limestone, dark-gray, dense, bedded; ostracods abundant; fish plates | 0 | 1 | 91 | 1 |
| 5. Coal, bony, sooty, highly weathered. UNIONTOWN | 0 | 2 | 91 | 0 |
| 4. Clay shale, olive-drab, nonbedded, hard, very slightly calcareous, sandy | 2 | 5 | 90 | 10 |
| 3. Shale and limestone interbedded. Limestone, medium-gray, argillaceous, bedded (beds 3 to 4 feet thick); desiccation breccia. Shale, purple, red, dark-gray, calcareous; abundant limestone nodules; middle 15 or 20 feet very poorly exposed, top 30 feet exposed, top with abundant 2- to 3-foot limestone beds. BENWOOD-UNIONTOWN | 62 | 0 | 88 | 5 |
| 2. Clay shale, red, green, olive-drab, nonbedded, calcareous, sandy; contact with underlying sandstone covered | 1 | 9 | 26 | 5 |
| 1. Sandstone, olive-green, medium- to coarse-grained, massive to platy; cutting out Sewickley coal | 24 | 8 | 24 | 8 |

### Hockingport sandstone

Sandstone bodies over 20 feet thick are present at several localities in the county at an average of 50 feet above the Uniontown coal (pls. 4, 5). Sandstone in this position at Waynesburg, Pennsylvania, was called the Waynesburg sandstone by Stevenson (1873, p. 16).

A nomenclatural problem exists with sandstone in this position in Washington County if the coal beneath it is correlated with the Little Waynesburg (O.G.S. 15291, opposite). In Ohio sandstone lying above the Little Waynesburg coal carries the name Gilboy; Sturgeon (1958, p. 188) has suggested that sandstone in the position of the Waynesburg in the Washington County area represents coalesced Gilboy and Waynesburg. He has further suggested (p. 208) that where the unit is extremely thick it may consist of the coalesced Gilboy, Waynesburg, and Mannington sandstones.

Martin (1955) studied and described the large sand body in the stratigraphic position of the Waynesburg sandstone in western Washington, eastern Athens, and Meigs Counties, as well as in adjacent areas of West Virginia. He referred to this unit as the Hockingport sandstone. The areal distribution of the Hockingport sandstone as mapped by Martin is shown by figure 10, which is taken from a subsequent discussion of the unit by Martin and Henniger (1969). For clarity, county boundaries and names have been added and cross-section lines removed from Martin's original

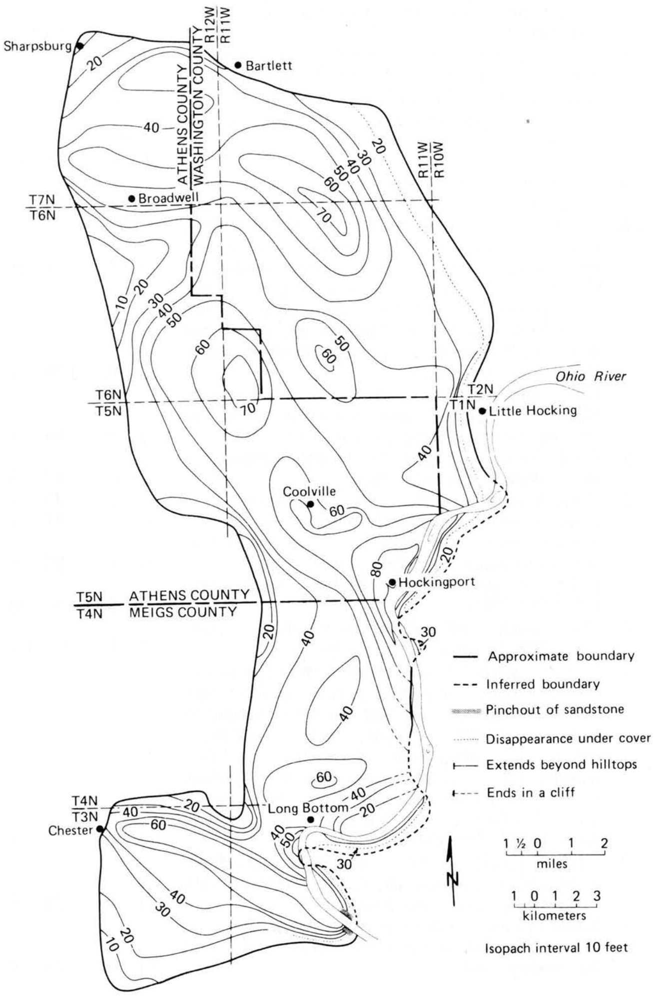


FIGURE 10.—Distribution and thickness of the Hockingport sandstone lentil in Washington County, Ohio, and adjacent areas (modified slightly from Martin and Henniger, 1969, p. 285).

map. Martin and Henniger (p. 297) proposed that

> the Hockingport Sandstone be considered a lentil of the lower part of the Dunkard Group.

These authors consider the Hockingport and Mather (type Waynesburg) to be homotaxial units and argued:

> In time, when the stratigraphy of the Dunkard sequence is better understood, this formal name and classification of the sandstone body would likely be compatible with the scheme of nomenclature devised for that part of the Appalachian basin.

On the basis of correlations suggested by this study and the nomenclatural problems arising from the lack of a definitely identifiable Waynesburg coal, it seems unwise to correlate the unit described by Martin and Henninger with the Waynesburg sandstone. The name Hockingport is used here as a matter of convenience pending further studies.

The Hockingport sandstone is the most impressive sandstone body in the area. It is easily traced throughout its area in western Washington County by its relatively great thickness, massive bedding, coarse-grained to conglomeratic character, and cliff-forming properties. Reentrants and small rock overhangs are common features of this unit, and a small natural bridge has been formed just west of the township road in the center of the southwest quarter of sec. 18, Fairfield Township.

The base of the unit is located from 20 to 50 feet above the Uniontown coal and the sandstone is from slightly under 20 to over 90 feet thick in the area mapped. The following description of the grain-size variation in the Hockingport is quoted from Martin (1955, p. 24-25):

> The grain size of the Hockingport sandstone varies from pebbles an inch or more in diameter to fine sand or even silt and clay-size material, but the major portion is that of very coarse sand. Coarse conglomerate occurs in greatest abundance near the base of the member. Some of the conglomeratic lenses are well-sorted into pebbles of nearly the same size, but lenses containing a mixture of argillaceous material, sand, granules and abundant scattered pebbles are more common. Very coarse sand is for the most part limited to the lower half of the sandstone deposit. Most of the remainder of the sandstone is composed of coarse sand but generally grading into medium and fine sand at the top. There is then, a gradation in grain size from the coarser material at or near the base of the sandstone to finer material at the top. However, many irregularities occur to this gradational sequence in the grain size of the deposit. Lenses of conglomerate occur 20 to 30 feet above the base, and thin lenses of fine sand, very fine sand, or siltstone occur at random within the deposit. It is not unusual to find a thin zone, or even a single row of pebbles occurring along a lamination plane, or scattered pebbles occurring in a matrix of granule conglomerate or very coarse sandstone.
>
> The grain size of the deposit changes abruptly both laterally and vertically where the channel structures are best developed. Within any one channel the size gradation is generally from the coarser material at the bottom into progressively finer material toward the top. Commonly a lens of pebble conglomerate exists at or near the base of a channel structure.

Martin (1955) reports that the Hockingport is a subgraywacke averaging 65 percent quartz, with fragments and argillaceous material making up the remainder. The pebble zones are composed predominantly of quartz, but sandstone, siltstone, chert, and feldspar pebbles are also found. Fossiliferous chert pebbles reported by Martin (p. 41) were found also by the authors, although no paleontologic data are available at this time.

In some places (pl. 5) thick lenses of shale, siltstone, or mudstone are interbedded with the massive sandstone. Along the eastern and northeastern flanks of the unit the sandstone is split into upper and lower tongues by a wedge of argillaceous rocks (pl. 5, O.G.S. 15013, 15001). The authors feel that this feature represents intertonguing of synchronous beds and hence essentially marks the eastern boundary of the sand body, although the actual boundary is below drainage. Along the western edge of the county, lenses of shale or mudstone, generally 5 feet thick or less, are found at various positions in the sandstone. These lenses are considered merely local accumulations of argillaceous materials.

In eastern Washington County several sandstone bodies with thicknesses greater than 20 feet are found approximately 50 feet above the Uniontown coal. Although these sandstones occupy the same relative stratigraphic position as the Hockingport, the genetic relationship between the units is not clear. These sandstones are rather restricted areally and are found mostly in northwest-southeast-oriented lenses which intertongue laterally with shale. On the whole the sandstones differ from the Hockingport sand body in that they are fine to medium grained and tend to be shaly and irregularly bedded. They are coarse grained and massive in a few places only.

### Waynesburg coal

The third coal smut, an average of 80 feet above the Uniontown coal, is found in the central portion of Washington County (fig. 11). This unit, similar to the other thin smuts in this sequence, ranges from a few inches to a few feet in thickness and from carbonaceous clay to black shale or, rarely, highly weathered coal. Although this smut does not fully correspond with any of the named coals between the Uniontown and Washington coals, it is here tentatively correlated with the Waynesburg.

The Waynesburg coal is the highest unit in the Monongahela Group and until the work of Cross (1958) was considered to be the boundary between Permian and Pennsylvanian rocks in the northern Appalachian Basin. A fuller discussion of this boundary can be found in the section on the Permian System. This coal takes its name from the town of Waynesburg, Greene County, Pennsylvania (Rogers, 1858, p. 506-507). White (1891, p. 29) correlated the Waynesburg coal into Liberty Township, Washington County, Ohio, on the basis that the Macksburg coal of Ohio geologists was the equivalent of the Waynesburg coal. It has since been shown, however, that the Macksburg coal of early usage is correlative with the Meigs Creek and not with the Waynesburg.

The following stratigraphic section illustrates the general nature of the Waynesburg and the overlying Waynesburg "A" coals.

O.G.S. 8808, Salem Twp., x = 2,298,200 feet, y = 560,400 feet, Lower Salem 7½- and Macksburg 15-minute quadrangles. Measured along stream and eroded slope to top of hill at road junction at elevation 980 feet. Measured by G. Bell. Base elevation 751 feet.

| | *ft* | *in* | *ft* | *in* |
|---|---|---|---|---|
| 50. Shale, dark-red and gray, slightly mottled, poorly exposed | 3 | 0 | 200 | 5 |
| 49. Clay shale, chocolate; weathering to chips; containing nodules of flint(?) clay up to 2 inches in diameter | 0 | 6 | 197 | 5 |
| 48. Clay shale, greenish-gray; weathering to ¼- to ½-inch chips or plates (chippy) | 1 | 0 | 196 | 11 |
| 47. Limonite, nodules and concretions ½ inch in diameter | 0 | 1 | 195 | 11 |
| 46. Coal, shaly, highly weathered; some bright blocky pieces. WAYNESBURG "A" | 0 | 2 | 195 | 10 |
| 45. Clay shale, yellowish-brown, very ferruginous | 0 | 1 | 195 | 8 |
| 44. Clay shale, light-greenish-gray, clayey to silty, very calcareous; containing a few very argillaceous gray limestone nodules up to 1 foot in diameter; making light-greenish scar on eroded slope | 2 | 7 | 195 | 7 |
| 43. Clay shale, red- and gray-mottled, clayey to silty, very calcareous; some flint(?) clay nodules up to 3 inches in diameter | 1 | 0 | 193 | 0 |
| 42. Shale, dark-red, poorly exposed | 3 | 7 | 192 | 0 |
| 41. Shale, variegated, dark-red, greenish-gray, brown, and purple, mottled, silty to clayey | 2 | 0 | 188 | 5 |
| 40. Limestone, greenish-gray to tan, argillaceous, somewhat nodular | 0 | 5 | 186 | 5 |
| 39. Shale, variegated dark-red, purple, gray, and brown, silty, very calcareous; abundant nodules up to 2 inches in diameter of finely crystalline gray to greenish-gray limestone, in part very argillaceous | 4 | 0 | 186 | 0 |
| 38. Shale and siltstone, greenish-gray, micaceous; containing scattered nodules of very argillaceous brown limestone up to 2 inches in diameter; nodules more numerous upward | 4 | 3 | 182 | 0 |
| 37. Shale, dark-red, silty, very calcareous in uppermost 3 feet | 7 | 9 | 177 | 9 |
| 36. Covered | 5 | 8 | 170 | 0 |
| 35. Clay shale, dark-reddish-brown; weathering to small ¼- to ½-inch plates or chips (chippy) | 0 | 6 | 164 | 4 |
| 34. Clay shale, variegated dark-red, brown, silty; small amount purple | 0 | 8 | 163 | 10 |
| 33. Shale, black, very carbonaceous; possibly a highly weathered coal. WAYNESBURG | 0 | 1 | 163 | 2 |
| 32. Clay, light-gray, somewhat plastic | 0 | 1 | 163 | 1 |
| 31. Clay shale, greenish-gray, slightly silty | 0 | 6 | 163 | 0 |
| 30. Sandstone, gray to brown, very fine-grained; apparently interbedded with gray to greenish-gray shale; poorly exposed | 7 | 2 | 162 | 6 |
| 29. Covered | 39 | 4 | 155 | 4 |
| 28. Sandstone, gray to greenish-gray, very fine-grained; massive with some shaly lenses; may be disconformable at base | 6 | 0 | 116 | 0 |
| 27. Shale, dark-red, silty to sandy; grading upward to greenish-gray siltstone | 3 | 0 | 110 | 0 |
| 26. Covered | 3 | 0 | 107 | 0 |
| 25. Sandstone, gray to brown, very fine-grained, and siltstone, highly cross-bedded, shaly to medium-bedded; unit apparently disconformable at base | 9 | 0 | 104 | 0 |
| 24. Shale, red, sandy; becoming gray at top | 2 | 0 | 95 | 0 |
| 23. Covered | 2 | 0 | 93 | 0 |
| 22. Clay shale, dark-red, clayey to silty | 1 | 0 | 91 | 0 |
| 21. Clay shale, light-gray, plastic-weathering | 0 | 3½ | 90 | 0 |
| 20. Coal, shaly, highly weathered | 0 | ½ | 89 | 8½ |
| 19. Clay shale, gray, somewhat plastic-weathering | 0 | 7 | 89 | 8 |
| 18. Limestone, gray, very argillaceous, shaly | 0 | 6 | 89 | 1 |
| 17. Clay shale, gray to brown, clayey to silty | 0 | 5 | 88 | 7 |
| 16. Coal, shaly, poorly exposed | 0 | ½ | 88 | 2 |
| 15. Clay shale, brown at base, becoming dark gray at top; clayey. UNIONTOWN | 0 | 4 | 88 | 1½ |
| 14. Coal, shaly, highly weathered | 0 | ½ | 87 | 9½ |
| *Units 1 through 13 omitted. Section modified slightly from original* | | | | |

### Waynesburg "A" coal

A fourth smut, relatively widespread (fig. 12) at an average of 107 feet above the Uniontown coal, is present in the stratigraphic position of the Waynesburg "A" and is in most respects similar to the other smuts between the Uniontown and Washington coals.

This smut is found from 80 to 120 feet above the Uniontown. It is possible that clusters of sections at comparable elevations may represent discrete depositional areas; for instance, most sections in Watertown and Waterford Townships have an interval of about 80 feet between this smut and the Uniontown coal. The unit is normally only a few inches of coaly shale or carbonaceous clay, but is represented by coal in a few places (O.G.S. 8808, opposite). In the vicinity of the village of Watertown this unit is commonly composed of two or three benches of coal or carbonaceous clay or shale separated by shale or clay a few inches to 10 feet thick. Bright blocky coal as much as 2 feet thick is found in this area in a few places.

### Mannington sandstone

A large thick sandstone body occupying the relative position of the Mannington sandstone of Grimsley (1909, p. 440-441) is found in easternmost Washington County. Several smaller sand bodies are present in the same position in the central and western areas (fig. 13) of the county.

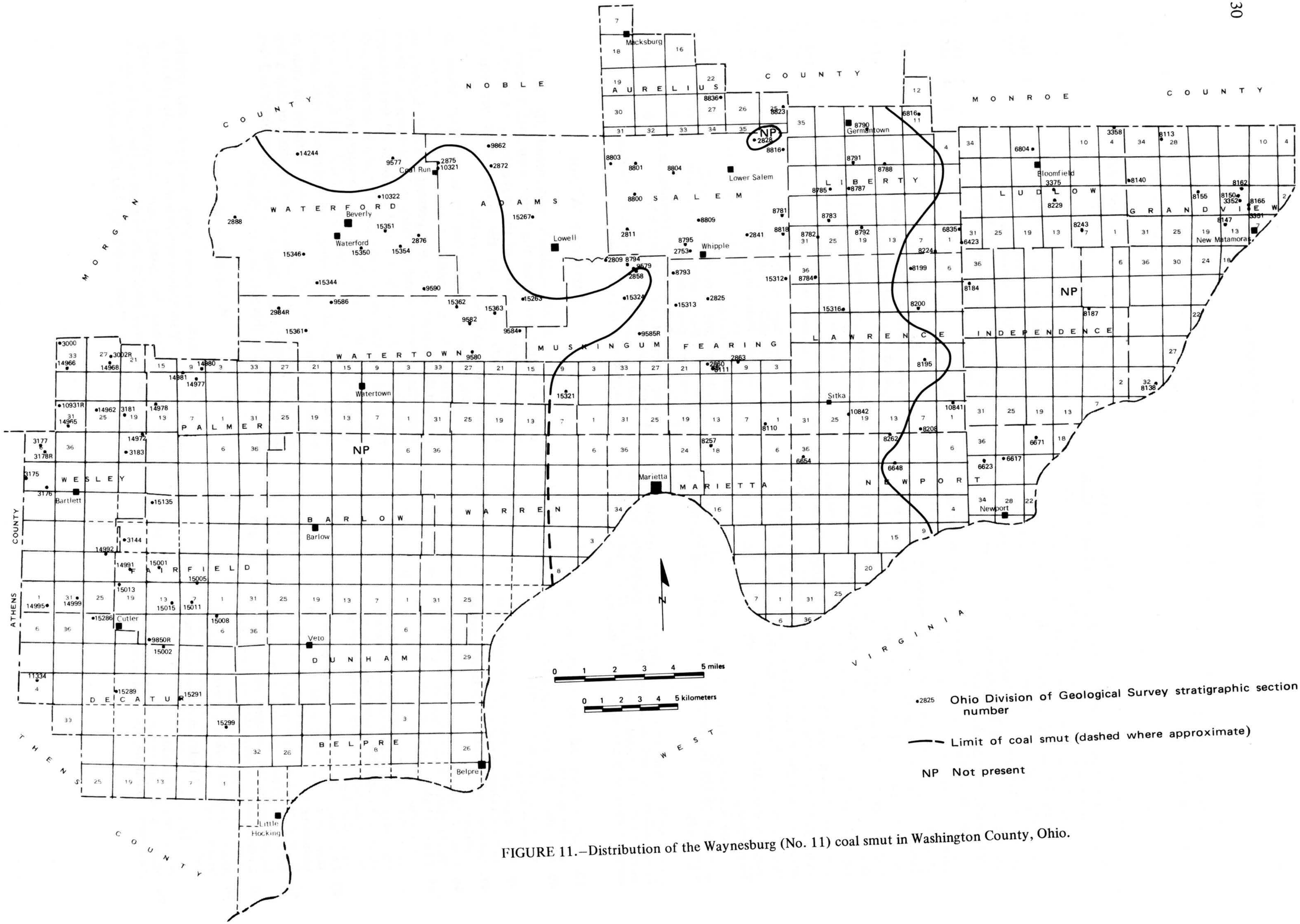


FIGURE 11.–Distribution of the Waynesburg (No. 11) coal smut in Washington County, Ohio.

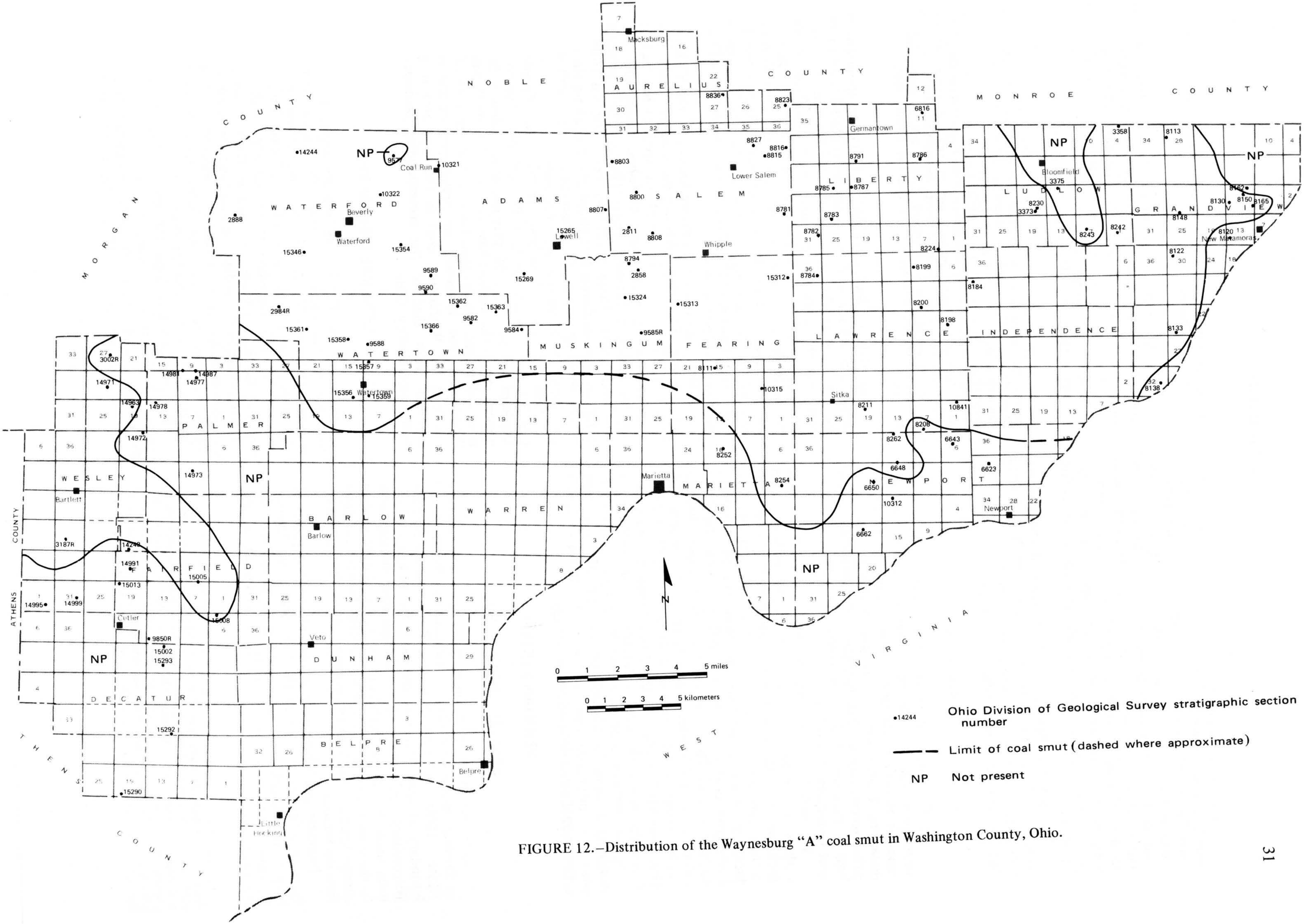


FIGURE 12.–Distribution of the Waynesburg "A" coal smut in Washington County, Ohio.

The eastern sand body is similar in many respects to the stratigraphically lower Hockingport sandstone. The unit is generally a cliff-forming micaceous massive medium- to coarse-grained buff and tan sandstone. Fine-grained, calcareous, or friable sandstone is found in some localities. The unit reaches a thickness of 86 feet at its thickest known point (O.G.S. 8242, Ludlow Township) and intertongues to both the east and west with sandy shales, thinning to the point that it becomes unrecognizable as a discrete body (fig. 13, pl. 4).

The isolated patches of thick sand in the western portion of the county tend to be fine to medium grained rather than medium to coarse grained, and bedding is more shaly than in the corresponding eastern sand.

### Unnamed coal

The fifth and last smut between the Uniontown and Washington coals is the only one to have potentially mineable thickness. The unit, found an average of 135 feet above the Uniontown coal, ranges from a few inches of carbonaceous clay or shale to slightly over 50 inches of coal. Coal of mineable thickness is confined entirely to easternmost Grandview Township.

This unit has been called the Waynesburg "A" by most workers in the area, but, because of the relatively great thickness of rocks between it and the Uniontown coal, the authors consider this correlation incorrect. Similarly, the thickness of rocks between this unit and the overlying Washington coal rules out a correlation with the Little Washington coal. This smut is found at fewer places than the lower smuts in this interval and its area of occurrence (fig. 14) is correspondingly less well defined. O.G.S. 3349, 3351, 8160, and 8162 of plate 4 suggest that in eastern Grandview Township, where the coal is thickest, it may intertongue along its western edge with the Mannington sandstone. Assigning a name to this unit on the basis of the limited amount of information available would be premature; such action should await detailed regional study.

## PERMIAN SYSTEM

### SYSTEMIC BOUNDARY

In the northern Appalachian Basin, rocks now classified as Permian in age were first so designated by Fontaine and White (1880, p. 119-120); the Pennsylvanian-Permian boundary at that time was placed at the position of the Waynesburg coal. Many minor changes have subsequently been made by various authors in the nomenclature applied to these units (see table 1). More recently, however, a major change has been made in the position of the Pennsylvanian-Permian boundary.

Fontaine and White were of the opinion that plants of Permian affinities dominated the flora above the Waynesburg coal, although such plants could be found as low as the Conemaugh. Cross (1958, p. 194), in a restudy of the Dunkard flora, stated:

> There are a number of genera recorded in the Dunkard flora . . . of which we have several representatives which are considered to indicate a much later age than the Monongahela-Conemaugh and upper Allegheny, i.e., Permian. There seems little doubt as to the general evolution of the flora and the sparse addition of a few new genera or species, but for the most part the sequence indicated from the upper Allegheny through the Dunkard seems to reflect a great dying out of prominent middle and upper Pennsylvanian (uppermost Carboniferous) plants.

Cross also reported that undisputed *Callipteris conferta*, which has been considered by many to be an index fossil of the Permian, was not found below the Washington coal.

The importance of Cross' statement concerning the occurrence of *Callipteris* may be seen in the following statement taken from Berryhill (1963, p. 47):

> Based on Cross' study of the flora, the Pennsylvania Geological Survey had planned to redesignate the Washington formation as Pennsylvanian in age and to reclassify the Greene formation as Pennsylvanian and Permian on the forthcoming new geologic map of Pennsylvania. On November 1, 1959, representatives of the U.S. Geological Survey and representatives of the Pennsylvania, Ohio, and West Virginia Geological Surveys met in conference and formally revised the age of the Dunkard group. Henceforth, the Washington formation (lower part of Dunkard group) will be designated as Pennsylvanian and Permian in age and the Greene formation as Permian.

Berryhill and Swanson (1962, p. C43) later (publication delays account for discrepancy in dates) placed the base of the Permian at the base of the Washington coal and redefined the sequence of rocks from the base of the Washington coal to the top of the upper limestone member (formerly the Upper Washington Limestone) as the Washington Formation of Early Permian age. The rocks between the base of the Waynesburg and the base of the Washington coals were designated the Waynesburg Formation of Pennsylvanian and Permian age.

A recent discovered vertebrate locality in the SW¼ sec. 26E, Belpre Township, Washington County, Ohio (see O.G.S. 15231, p. 39, for details of section) has yielded remains of at least 11 genera of fishes, amphibians, and reptiles having a Permian aspect (Baird, 1967, personal communication). These specimens were collected from a conglomeratic sandstone lens about 207 feet above the base of the Washington coal. This material is located well above the base of the Permian as described above.

Gillespie and Clendening (1969) and Clendening (1970c) have argued for Late Pennsylvanian age for the Dunkard on the basis of palynological evidence. In the present report the authors have followed Berryhill's convention and placed the Permian boundary at the base of the Washington coal. However, the stratigraphy of the rocks overlying the Washington coal in the type area is quite different from that of the corresponding sequence in Washington County, Ohio.

### GENERAL CHARACTER

Rocks of the Permian System are exposed in every township in the county; however, the largest area and greatest thickness, 400-420 feet, are found in Warren Township along the central axis of the Parkersburg-Lorain syncline (pl. 10). Elsewhere in the county much of the sequence has been removed by erosion. The Permian rocks are very similar to the underlying rocks and are composed of a repetitive sequence of relatively abundant thick sandstones, calcareous red mudstones, shales, and siltstones, with a few thin beds of coal and limestone.

The generalized geologic column of Ohio (Stout and others, 1943) listed 18 named Permian units above the Washington coal: (1) Lower Marietta sandstone, (2) Lower Washington limestone, (3) Middle Washington (Creston

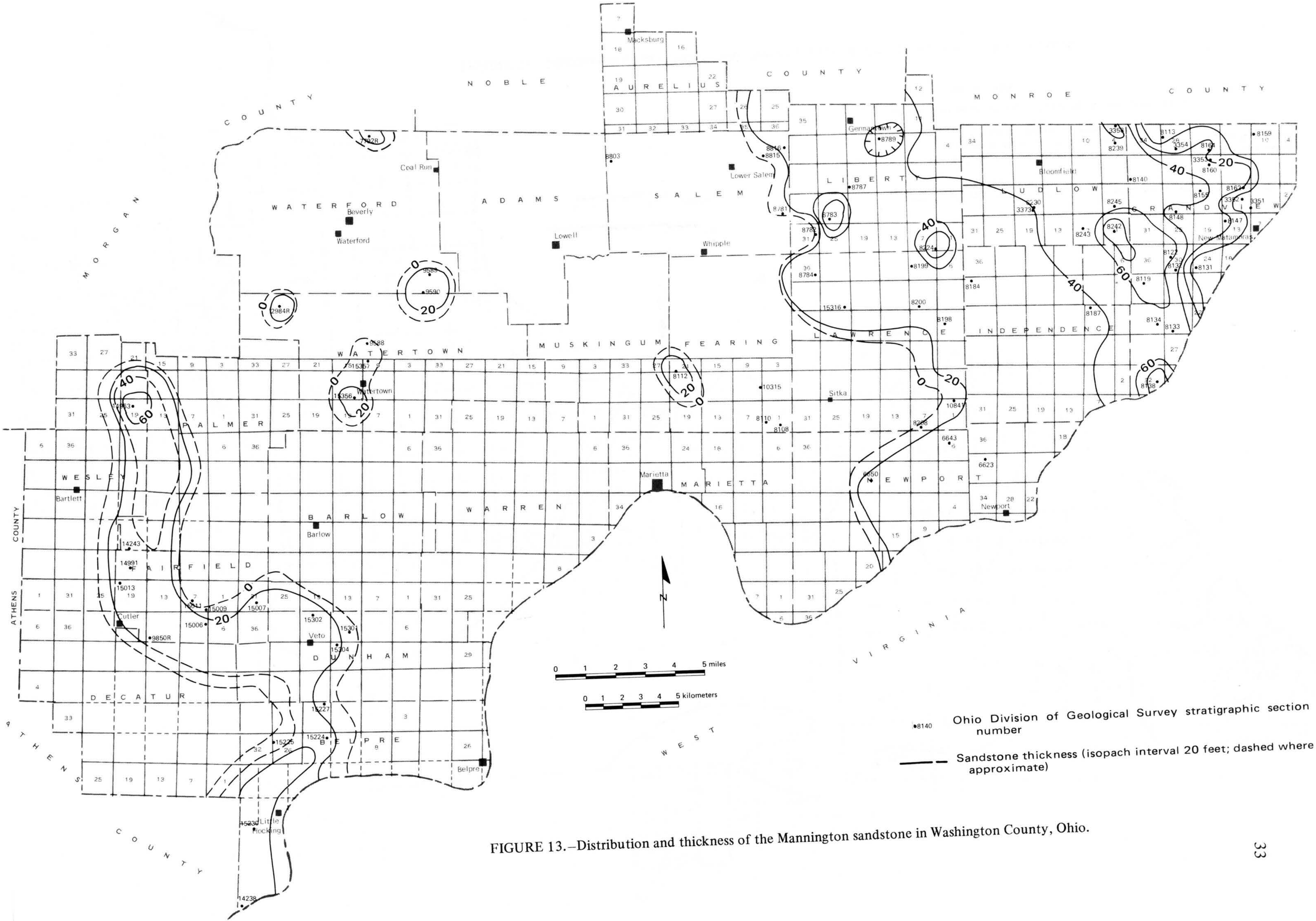


FIGURE 13.–Distribution and thickness of the Mannington sandstone in Washington County, Ohio.

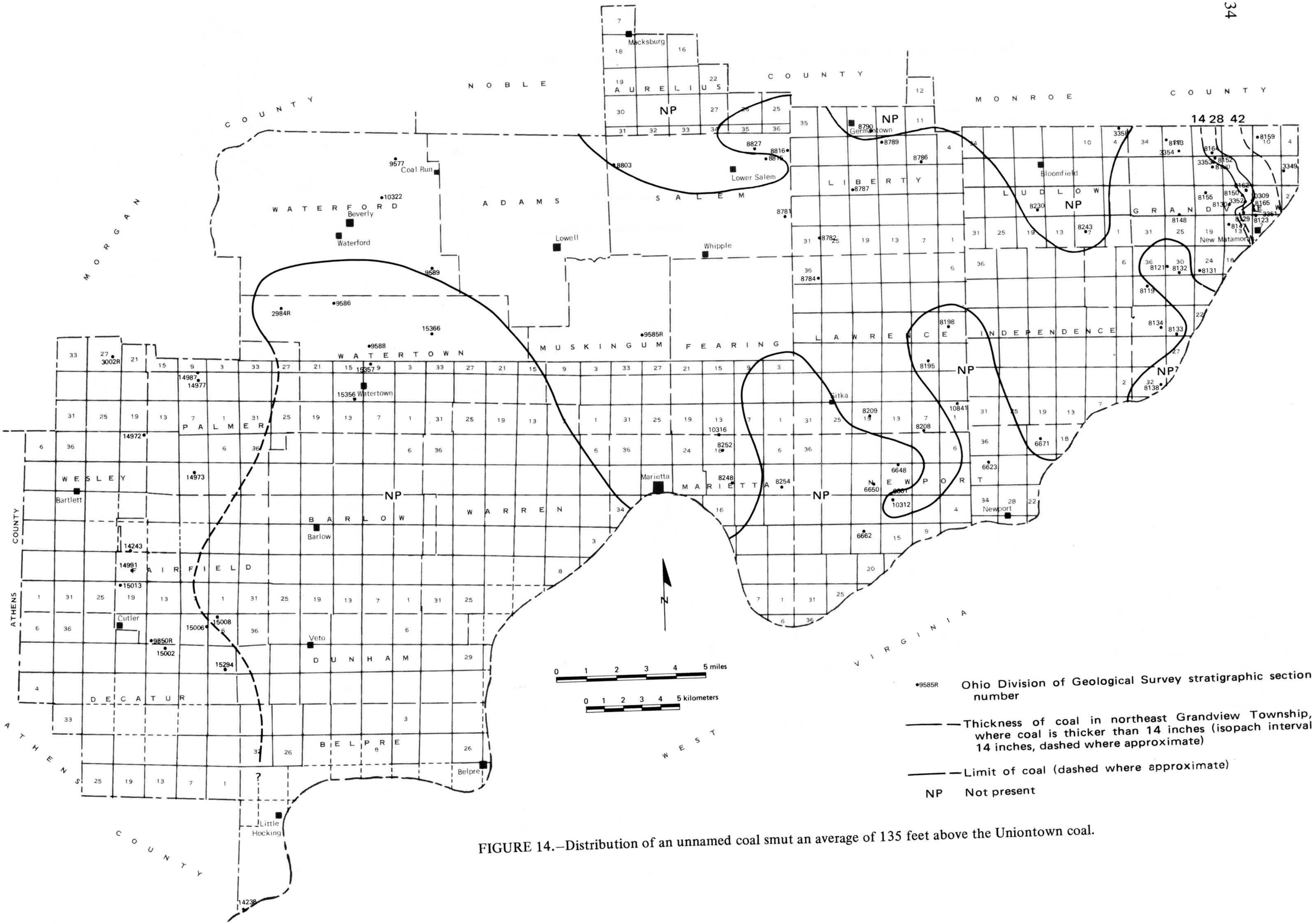


FIGURE 14.–Distribution of an unnamed coal smut an average of 135 feet above the Uniontown coal.

Reds) limestone, (4) Washington "A" coal, (5) Upper Marietta sandstone, (6) Hundred sandstone, (7) Upper Washington shale, (8) Jollytown "A" coal, (9) Jollytown sandstone, (10) Dunkard coal, (11) Fish Creek sandstone, (12) Fish Creek coal, (13) Hostetter coal, (14) Nineveh limestone, (15) Nineveh coal, (16) Nineveh sandstone, (17) Gilmore limestone, and (18) Gilmore sandstone. Berryhill (1963, p. 48-49) lists 14, and Stauffer and Schroyer (1920, p. 19-23) have 16 named units in the same interval. Cross and others (1950) and Cross and Arkle (1951) informally used the terms Washington Rider "A," Washington Rider "B," and Washington Rider "C" to identify coal smuts occurring in approximately the first 50 feet of rocks overlying the Washington coal. In Washington County only the Washington Rider "B" coal, the Creston Reds, and the Marietta sandstones are definitely correlated and these units are recognized only in restricted areas.

## DESCRIPTION OF UNITS

### Washington coal

The Washington coal bed, named by Stevenson (1876, p. 51) from outcrops at Washington, Pennsylvania, is the highest persistent coal in the Pennsylvanian-Permian sequence of eastern United States (Berryhill and Swanson, 1962, p. C46). The bed or its lateral equivalent is found rather consistently throughout Washington County about 195 feet above the Uniontown coal.

The bed ranges from a definite bright blocky coal to carbonaceous clay or coaly shale (fig. 15). The unit is quite thin, ranging from only a few inches to about 2 feet in thickness. Nowhere in the county can this coal be considered a real economic resource; even in those areas where the coal reaches a thickness of about 2 feet the unit is generally somewhat shaly and bony and is broken by numerous clay or shale partings. Over much of the county carbonaceous clay or shale surrounds and is continuous with the areas of blocky coal (fig. 15). The coal is assumed to be represented laterally by this shale or by streaks of carbonaceous debris in the upper portion of the underclay.

The Washington coal is not present in most of Adams, Aurelius, and Waterford Townships because of lack of sufficient stratigraphic interval to encompass the unit. In Decatur, Fairfield, Palmer, and Wesley Townships the coal or its lateral equivalent becomes less distinct and the unit is not correlated through these townships.

The Washington coal is generally underlain by a distinctive plastic to semiplastic light-gray to greenish-gray, red-variegated clay. This clay ranges from a few to about 25 feet in thickness and is commonly calcareous, with abundant limestone nodules, particularly in the lower part.

The coal is generally overlain by a thin clay or mudstone which in turn is overlain by a plant-bearing fissile red shale. However, at some localities the shale rests directly on the coal.

This sequence of underclay, coal, clay (mudstone), and shale, with modification, is remarkably persistent throughout the county. The following three sections are representative:

O.G.S. 15357, Watertown Twp., x = 2,244,900 feet, y = 540,750 feet, Watertown 7½- and Parkersburg 15-minute quadrangles. Measured starting on east side of Ohio Rte. 76, ¼ mile northwest of Plumb Run Road and going southeast along 76 to ¼ mile southeast of Plumb Run Road in sec. 9, continuing to top of road cut near North Watertown Cemetery. Measured by H. R. Collins and B. E. Smith. Base elevation 680 feet (topographic map).

| | *ft* | *in* | *ft* | *in* |
|---|---|---|---|---|
| 20. Sandstone, brownish-yellow to buff, medium- to coarse-grained; unit highly weathered; thickness estimated. LOWER MARIETTA | 14 | 0 | 118 | 7 |
| 19. Shale, red, fissile, thin-bedded, clayey; plant compressions and impressions | 3 | 0 | 104 | 7 |
| 18. Clay, dark-gray; grading upward into nonbedded carbonaceous slightly silty light-gray mudstone mottled red and green | 7 | 11 | 101 | 7 |
| 17. Coal; carbonaceous shale to coaly shale | 0 | 5 | 93 | 8 |
| Clay, medium- to dark-gray, nonbedded; plastic when wet | 0 | 4 | 93 | 3 |
| Coal, bony; some bright and blocky; abundant fusain. WASHINGTON | 0 | 4 | 92 | 11 |
| 16. Clay, maroon to reddish-brown; yellowish in places; becoming bluish gray to yellow near top; top 1 foot medium-gray clay; lenses and pods of very sandy clay; abundant limestone nodules; ironstone concretions | 19 | 4 | 92 | 7 |
| *Units 1 through 15 omitted* | | | | |

O.G.S. 8267, Newport Twp., x = 2,324,050 feet, y = 530,575 feet, Belmont and Willow Island 7½- and Marietta 15-minute quadrangles. Measured beginning at junction at elevation 895 at top of hill in north-central sec. 32 and continuing northward down hill to junction at elevation 736 in south-central sec. 33. Measured by W. H. Smith and M. O. Berry. Base elevation 738 feet (topographic map).

| | *ft* | *in* | *ft* | *in* |
|---|---|---|---|---|
| *Units 1 through 19 omitted* | | | | |
| 20. Sandstone, greenish, hard, fine-grained, calcareous; conspicuous ledge | 0 | 4 | 27 | 5 |
| 21. Sandstone, greenish-gray, fine-grained, soft | 1 | 0 | 27 | 1 |
| 22. Shale, deep-red; interbedded with siltstone | 4 | 6 | 26 | 1 |
| 23. Shale, pink, chippy; interbedded with siltstone | 5 | 6 | 21 | 7 |
| 24. Sandstone, blue-gray, fine-grained, thin-laminated | 4 | 6 | 16 | 1 |
| 25. Shale, pink, chippy; numerous plant fossils | 3 | 5 | 11 | 7 |
| 26. Clay, gray, plastic, slightly carbonaceous; coal horizon | 0 | 1 | 8 | 2 |
| 27. Clay shale, blue-gray; much ocher-yellow iron stain; weathering to soft clay soil | 4 | 0 | 8 | 1 |
| 28. Coal zone. WASHINGTON | | | | |
| 1. Clay shale, dark-gray, carbonaceous | 1 | 3 | 4 | 1 |
| 2. Clay shale, gray; with coaly streaks | 0 | 4 | 2 | 10 |
| 3. Coal, bright, blocky; numerous shaly and bony partings; some pyrite nodules | 0 | 6 | 2 | 6 |
| 4. Shale, very dark, carbonaceous, hard | 2 | 0 | 2 | 0 |

O.G.S. 15072, Marietta Twp., SE¼ of the SW¼ of the NE¼ sec. 34, Marietta 7½- and Marietta 15-minute quadrangles. Measured at junction of U.S. 50A and Ohio Rte. 7 on north side of road approximately 0.3 mile southwest of Marietta. Measured by B. E. Smith and H. R. Collins. Base elevation 640 feet.

| | *ft* | *in* | *ft* | *in* |
|---|---|---|---|---|
| *Units 16 through 22 omitted* | | | | |
| 15. Shale, dusky-red, thin-bedded, slightly silty, micaceous; highly oxidized; limestone nodules and small lenses scattered throughout uppermost portion | 2 | 6 | 42 | 0 |
| 14. Mudstone, dusky-red, nonbedded; weathering dark brown; hard compact unit | 3 | 9 | 39 | 6 |
| 13. Sandstone, iron-stained, micaceous; greenish gray to buff on weathered surface; massive above, slabby below | 3 | 9 | 35 | 9 |
| 12. Shale, dusky-red, thin-bedded; limestone nodules and lenses throughout | 2 | 1 | 32 | 0 |
| 11. Mudstone, greenish-gray, red-mottled, nonbedded; limestone nodules scattered throughout | 0 | 2 | 29 | 11 |
| 10. Sandstone, greenish-gray, fine-grained, iron-stained, micaceous; massive to slabby in | | | | |

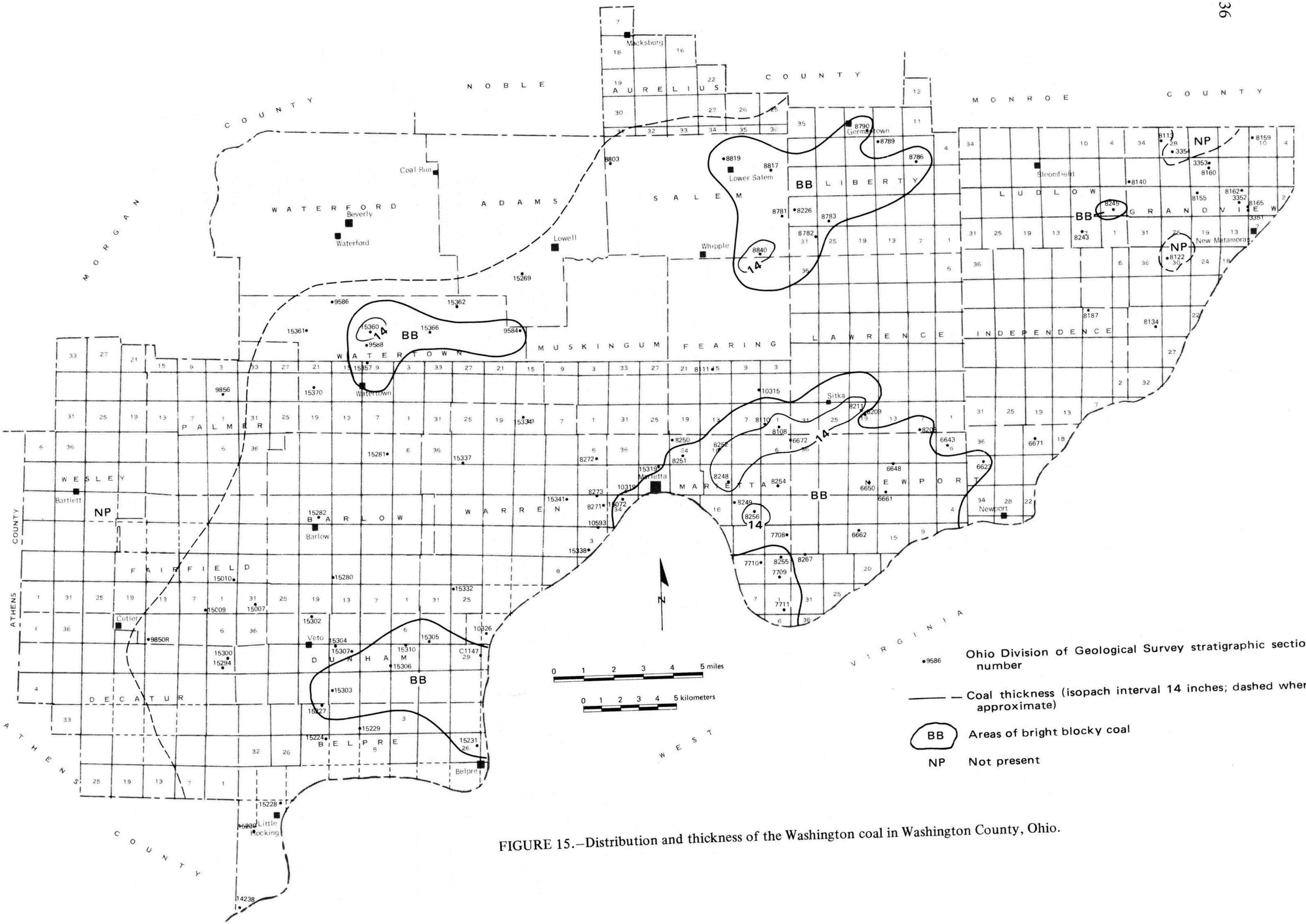


FIGURE 15.–Distribution and thickness of the Washington coal in Washington County, Ohio.

| | ft | in | ft | in |
|---|---|---|---|---|
| lower part | 6 | 0 | 29 | 9 |
| 9. Shale, dusky-red; thin- to massive-bedded upward; slickensided; gradational into unit above | 1 | 9 | 23 | 9 |
| 8. Shale, greenish-gray, red-mottled, thin-bedded, plant-fossiliferous; bits of coal present on bedding planes | 0 | 5 | 22 | 0 |
| 7. Mudstone, greenish-gray, red-mottled, iron-stained, nonbedded, slightly calcareous | 5 | 0 | 21 | 7 |
| 6. Coal zone; dark-gray to black carbonaceous shale with coal stringers throughout; basal ½ inch of coal blocky, bony, with abundant fusain; 150 feet to northeast 1 foot of good bright blocky coal. WASHINGTON | 1 | 10 | 16 | 7 |
| 5. Clay, greenish-gray, iron-stained, nonbedded, slightly silty, micaceous; limestone lenses scattered randomly throughout unit with marked decrease at top | 6 | 3 | 14 | 9 |

*Units 1 through 4 omitted*

### Washington Rider "B" coal

Cross and Arkle (1951, p. 105, fig. 3) use the term Washington Rider "B" for a thin coal smut about 20 to 25 feet above the Washington coal.

In Washington County a thin smut is present approximately 25 feet above the Washington in about a dozen sections scattered in Grandview, Independence, Liberty, Marietta, and Newport Townships. These smuts are in the stratigraphic position of Cross and Arkle's Washington Rider "B" coal and are so correlated. The unit is very nonpersistent and consists of only a few inches of coal or carbonaceous clay. Identification of the unit is based wholly on its relative stratigraphic position above the Washington coal; the following stratigraphic section shows this relationship:

O.G.S. 8155, Grandview Twp., NW¼ sec. 20, New Matamoras 7½- and New Matamoras 15-minute quadrangles. Measured along secondary road just southeast of Salem Hall. Measured by A. T. Cross. Top of section elevation 1001 feet (topographic map).

| | *ft* | *in* | *ft* | *in* |
|---|---|---|---|---|
| 36. Shale, red-weathering; concealed to top of knob | 11 | 6 | 214 | 2 |
| 35. Clay shale, gray; weathering yellow | 0 | 1 | 202 | 8 |
| 34. Clay shale, gray, carbonaceous(?); with one dark (coaly?) streak at base. | 0 | 1 | 202 | 7 |
| WASHINGTON "A" coal horizon | | | | |
| 33. Shale, green-gray, marly(?), crumbly | 1 | 10 | 202 | 6 |
| 32. Shale, blue-green; weathering to blue-gray dust | 2 | 6 | 200 | 8 |
| 31. Shale, green to red; weathering red to fine chips | 12 | 0 | 198 | 2 |
| 30. Limestone, green, rubbly, silty | 0 | 8 | 186 | 2 |
| 29. Siltstone, green to tan; weathering red brown | 3 | 0 | 185 | 6 |
| 28. Shale, green to red; weathering chippy to platy | 7 | 6 | 182 | 6 |
| 27. Clay shale, greenish; weathering tan | 0 | 4 | 175 | 0 |
| 26. Coal zone: Coal, shaly, soft | 0 | 2 | 174 | 8 |
| Coal, blocky, much weathered | 0 | 2 | 174 | 6 |
| WASHINGTON RIDER "B" coal horizon | | | | |
| 25. Clay shale and shale, gray to red, poorly exposed | 4 | 2 | 174 | 4 |
| 24. Sandstone, drab-olive-green, very fine-grained; concealed below | 3 | 0 | 170 | 2 |
| 23. Concealed, with silty shales, tan weathering out, possibly sandstone above | 9 | 0 | 167 | 2 |
| 22. Shale, red, poorly exposed | 4 | 6 | 158 | 2 |
| 21. Clay shale, gray; weathering yellow to red | 3 | 6 | 153 | 8 |
| 20. Clay, gray, soft, plastic | 0 | 3 | 150 | 2 |
| 19. Coal zone: Coal, shaly, much weathered (1 to 3 inches) | 0 | 2 | 149 | 11 |
| Clay, gray, soft | 0 | 1 | 149 | 9 |
| Coal, shaly, much weathered | 0 | 1 | 149 | 8 |
| WASHINGTON coal horizon | | | | |
| 18. Clay shale, gray, poorly exposed | 1 | 5 | 149 | 7 |
| 17. Shale, green-gray; weathering drab blue-green almost to dust, with yellow iron flakes; poorly exposed below | 4 | 6 | 148 | 2 |
| 16. Siltstone (or fine-grained sandstone), green; weathering tan to chips; massive below | 22 | 0 | 143 | 8 |
| 15. Sandstone, gray-green to tan, massive, micaceous; medium to fine grained above; medium grained below; concealed at base | 23 | 0 | 121 | 8 |
| 14. Concealed, with some clay shale; gray weathering at base | 8 | 6 | 98 | 8 |
| 13. Coal zone: Coal, shaly, badly weathered | 0 | 4 | 90 | 2 |
| Clay shale, intermixed with coal | 0 | 2 | 89 | 10 |
| Coal, blocky to shaly, much weathered | 0 | 4 | 89 | 8 |
| | 0 | 4 | 89 | 8 |

*Units 1 through 12 omitted. Section modified slightly from original*

Smuts in the stratigraphic positions of the Washington Rider "A" and "C" coals were not identified by the authors.

### Lower Marietta sandstone

White (1891, p. 35) assigned the name Marietta Sandstones to a group of two or three sandstones found within the 100- to 125-foot sequence above the Washington coal. The type area is cited as being "in the hills below Marietta, Ohio," with no specific type section designated. Hennen formally used the terms Lower and Upper Marietta in 1909 (p. 215) and published a section (1911, p. 131) from the type locality area on the Ohio River, opposite Brisco, West Virginia, about 7 miles southwest of Marietta. His original section is reproduced below:

| | *ft* | *ft* |
|---|---|---|
| 1. Sandstone, JOLLYTOWN, and concealed | 40 | 40 |
| 2. Reds, dark; with limestone nuggets | 20 | 60 |
| 3. Sandstone, brown and bluish, fine-grained; quarried for grindstones. HUNDRED | 41 | 101 |
| 4. Reds, dark | 5 | 106 |
| 5. Concealed and sandstone | 16 | 122 |
| 6. Shales, dark-red | 15 | 137 |
| 7. Sandstone, bluish, medium grained with limestone conglomerate at base. UPPER MARIETTA | 52 | 189 |
| 8. Reds, and concealed 45' | | |
| 9. Sandstone 2' CRESTON REDS | 62 | 251 |
| 10. Reds 15' | | |
| 11. Sandstone, bluish, medium grained, micaceous, LOWER MARIETTA | 20 | 271 |
| 12. Concealed | 5 | 276 |
| 13. Coal, WASHINGTON, 9" to | 1 | 277 |
| 14. Fire clay shale, WASHINGTON | 10 | 287 |

Lower Marietta sandstone as used in this report refers to sand bodies found in the first 40 feet above the Washington coal (pl. 6; O.G.S. 15231, p. 39; 10326, p. 40; Hennen's section, above). Absence of the Washington coal usually precludes any but a very tentative correlation.

Sandstone bodies in the stratigraphic position of the Lower Marietta are highly variable, ranging from a few to 64 feet in thickness and from light bluish gray to greenish gray. These sandstones are predominantly fine to medium grained, although coarse sand is found in a few places, and are shaly to massive bedded. Thick sandstone is most common in Belpre, Dunham, Warren, and Watertown Townships (fig. 16). These thicker units thin rapidly away from a central axis and intertongue with laterally equivalent mudstones and shales (pl. 6), resulting in considerable confusion in identification of the Lower Marietta.

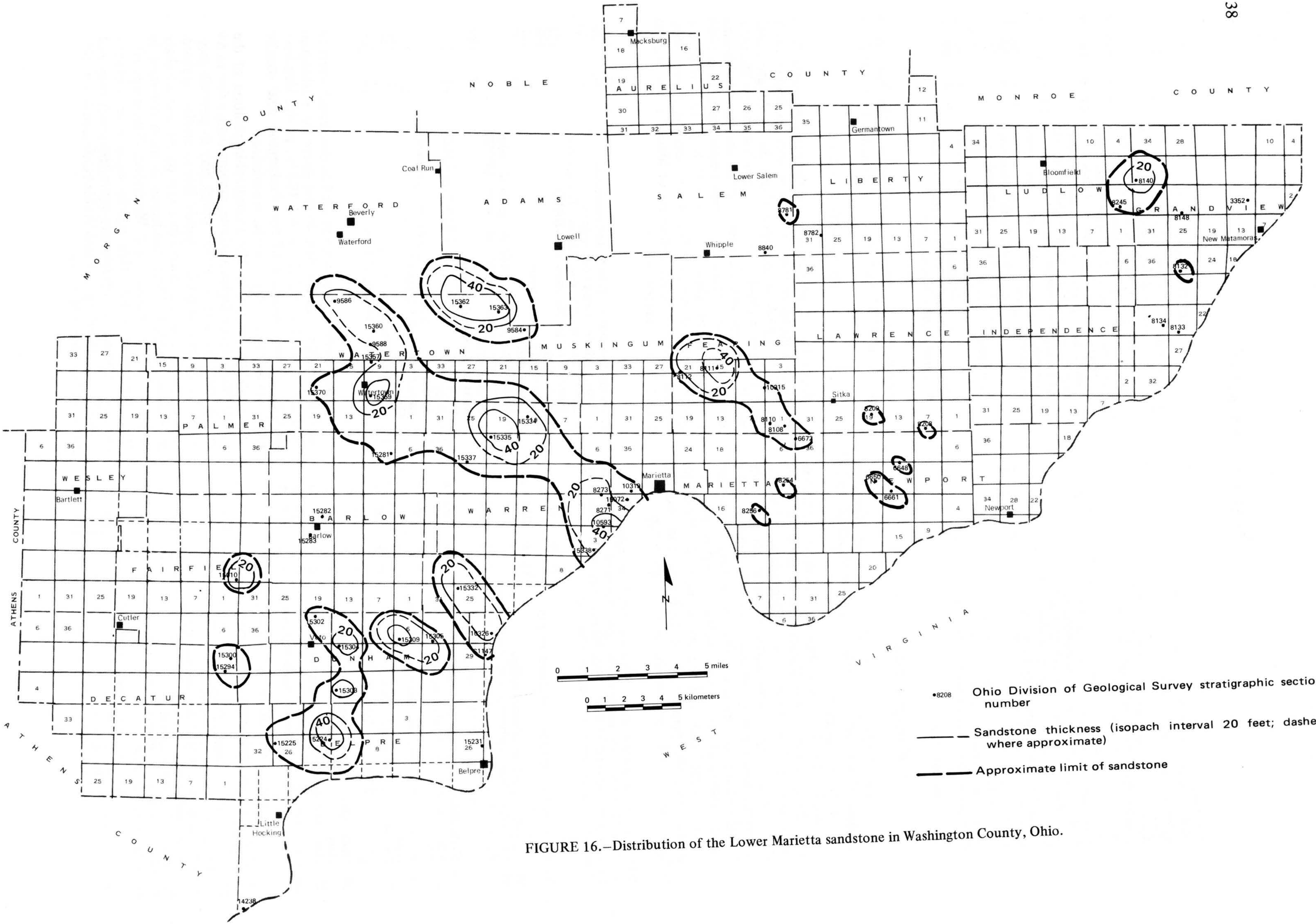


FIGURE 16.–Distribution of the Lower Marietta sandstone in Washington County, Ohio.

### Creston Reds

Hennen (1911, p. 154) identified a sequence of "dark red shale" lying between the Upper and Lower Marietta sandstones in West Virginia as the Creston Red Shale or Creston Reds.

In parts of Washington County nonbedded calcareous red mudstone with abundant limestone nodules and interbedded lenses of sandstone overlies the Lower Marietta sandstone (pl. 6; O.G.S. 15231, opposite; 10326, p. 40; Hennen's section, p. 37). This unit, at least in the southwestern portion of the county, is considered to be correlative with Hennen's Creston Reds, a term the authors prefer to the somewhat more specific Creston Red Shale.

The "typical" Creston Reds in the area to the west and southwest of Marietta is generally very calcareous, as much as 31 percent soluble in hydrochloric acid. Iron is present as a cementing agent; in one sample 2.6 percent iron by weight was removed, using a mixture of stannous chloride and hydrochloric acid.

A particle-size analysis of another sample, following treatment to remove both calcium carbonate and iron, revealed that the unit was comprised of 35 percent sand, 45 percent silt, and 20 percent clay. Size analyses run on untreated Creston Reds show an abnormally high sand fraction. This fraction is, however, mostly silt and clay aggregates which disaggregate into smaller size fractions when treated to remove the iron oxide cement.

The character and thickness of the Creston interval differ considerably throughout the county, as shown by plate 6. Mudstone averaging about 38 feet in thickness and similar to that of the type area is widespread west and southwest of Marietta in parts or all of Barlow, Belpre, Decatur, Fairfield, Warren, and Watertown Townships. Northeast of Marietta the Creston Reds thins rapidly and in general is lost as a distinct unit. Interbedded siltstones, sandstones, shales, mudstone, and a few rubbly limestones occupy the Creston interval in the northeasternmost section of the county (pl. 6D). Several samples of the Creston Reds were evaluated as a potential source of ceramic raw material. A discussion of these data are given in the mineral resources chapter.

### Washington "A" coal

White (1891, p. 35), reporting on the Washington "A" coal, stated:

> Bituminous shale is often found at this horizon in Washington and Greene Counties, Pennsylvania, and in Washington County, Ohio, a coal bed 2½ feet thick seems to occur at the same place in the series.

This statement is based on a section described by Minshall (1888) and cited by White (p. 29), who stated:

> These identifications are made on the supposition that the Macksburg coal of the Ohio geologists is the equivalent of the Waynesburg bed.

The name Macksburg was used by Minshall (1888) for what is now correlated as Meigs Creek, and this was the coal assumed by White (1891, p. 29) to be equivalent to the Waynesburg. White's 2½-foot coal compares favorably in stratigraphic position with the Little Waynesburg; however, the thickness is much greater than generally found for this coal.

An extremely thin (1- to 2-inch) carbonaceous clay confined to a few localities in Grandview, Ludlow, Marietta, and Warren Townships (pl. 6; O.G.S. 8155, p. 37) has been tentatively identified as the Washington "A" by some workers. Correlation with the Washington "A" coal is tenuous at best, and it appears to the authors that this smut has also been called the Washington Rider "C" coal in some sections.

### Upper Marietta sandstone

The Upper Marietta sandstone, named by Hennen (1909, p. 215), was identified in only a very few localities. Thick lenses of sandstone are present above the Creston Reds in the immediate area of Marietta, in the vicinity of Constitution and south to Belpre (see O.G.S. sections 15231, below, and 10326, p. 40, and near Glass in Grandview Township.

This sandstone or its position can be correlated definitely only where it can be related to the Washington coal. The Upper Marietta has essentially the same physical characteristics as the Lower Marietta, lacking lateral continuity (pl. 6) and consisting of a series of massive lenticular sand bodies which intertongue with adjacent sandy shales, siltstones, and mudstones. Thicknesses of over 50 feet are found in the Marietta and Constitution areas, where the unit was formerly extensively quarried for grindstones.

### Hundred sandstone

The Hundred sandstone was named by Hennen (1909, p. 214) from outcrops in the vicinity of Hundred, West Virginia, and the name was applied by him (1911, p. 131) to a sandstone lying above the Upper Marietta sandstone in Washington County, Ohio (section, page 37). The term was later formally used by Stauffer and Schroyer (1920, p. 20) in Ohio.

A sandstone in the position of the Hundred was found in a very few localities in the area between Marietta and Belpre (see O.G.S. 10326, p. 40). The meager evidence available suggests that the Hundred closely resembles the Marietta sandstones both in mode of occurrence and in physical characteristics. Grindstones were formerly quarried from this unit.

### Washington and Greene formations undifferentiated

Rocks of this interval are restricted largely to areas along the axis of the Parkersburg-Lorain syncline in Barlow, Belpre, Dunham, and Warren Townships. The sequence above the Hundred sandstone in Washington County consists of a repetitive series of poorly exposed sandstones, mudstones, shales, and siltstones. Coals, underclays, and limestones are conspicuous by their virtual absence. The argillaceous units weather readily and contribute to a relatively thick mantle which effectively masks the stratigraphy. The following two sections are representative of the few outcrops which were sufficiently well exposed to warrant description.

O.G.S. 15231, Belpre Twp., NE¼ of the NE¼ of the SW¼ sec. 26E, Parkersburg 7½- and Parkersburg 15-minute quadrangles. Measured along highway construction and borrow pit at village limits of Belpre about ¼ mile northwest of the Ohio terminus of the West Virginia

Memorial Bridge. Measured by H. R. Collins and B. E. Smith. Base elevation 584 feet.

| | ft | in | ft | in |
|---|---|---|---|---|
| 18. Mudstone, dusky-red, nonbedded, calcareous; limestone nodules abundant | 9 | 5 | 274 | 6 |
| 17. Sandstone, olive-drab, fine-grained, strongly calcareous; abundant limy nodules in uppermost part; gradational into the overlying unit | 3 | 0 | 265 | 1 |
| 16. Shale, dusky-red, medium-bedded; sandy upward; gradational with overlying and underlying units | 7 | 6 | 262 | 1 |
| 15. Mudstone, dusky-red, nonbedded; slickensides; calcareous with limestone nodules | 18 | 3 | 254 | 7 |
| 14. Sandstone, light-greenish-gray, fine-grained, massive, poorly exposed | 11 | 0 | 236 | 4 |
| 13. Sandstone and mudstone, interbedded. Sandstone, light-gray, fine-grained, massive. Mudstone, variegated red and gray, nonbedded; somewhat bedded and containing plant impressions about 11 feet from top | 13 | 0 | 225 | 4 |
| 12. Sandstone, greenish-gray, friable, very micaceous; containing bone fragments and teeth; basal 6 inches conglomeratic in places and containing vertebrate remains | 4 | 9 | 212 | 4 |
| 11. Mudstone, dusky-red to olive-gray to light-gray, nonbedded, silty, heavily slickensided | 22 | 0 | 207 | 7 |
| 10. Covered; few exposures suggesting that red mudstone and interbedded sandstone make up bulk of unit | 32 | 6 | 185 | 7 |
| 9. Shale, olive-drab to dusky-red, thick-bedded; sandy to sandstone, especially in top 2 feet | 12 | 10 | 153 | 1 |
| 8. Mudstone, dusky-red, variegated red and gray, nonbedded, silty, slickensided; covered at top | 19 | 3 | 140 | 3 |
| 7. Sandstone, olive-drab, fine-grained, slabby to massive to shaly, very micaceous, calcareous; gradational upper contact; sharp basal contact. UPPER MARIETTA | 26 | 2 | 121 | 0 |
| 6. Mudstone, variegated red and gray, mostly maroon, nonbedded, slickensided, calcareous; limestone nodules. CRESTON REDS | 39 | 7 | 94 | 10 |
| 5. Covered to railroad tracks | 18 | 9 | 55 | 3 |
| 4. Covered below railroad track level | 27 | 0 | 36 | 6 |
| 3. Shale, brown, very soft and crumbly, extremely weathered | 4 | 0 | 9 | 6 |
| 2. Coal, black, vitreous, mostly shaly; top 7 inches slightly weathered medium-firm carbonaceous clay shale. WASHINGTON | 1 | 6 | 5 | 6 |
| 1. Clay, gray, very soft, moist; containing pyrite | 4 | 0 | 4 | 0 |

*Units 1, 2, 3, and 4 added to the outcrop section from an Ohio Department of Highways core drilled from a point at or close to the base of the outcrop section. Description and thickness from Ohio Department of Highways soil profile at Sta 643+00, Was-7-11.93*

Stauffer and Schroyer (1920, p. 132-133) measured a section in Warren Township in which almost the entire Permian System was exposed as a result of quarrying operations. The section, which is no longer exposed, is reproduced here and compares well with Hennen's section (p. 37).

O.G.S. 10326, Warren Twp., sec. 30S, Parkersburg 7½- and Parkersburg 15-minute quadrangles. Measured along the Constitution Stone Company's tram road and through the quarries to top of hill. Measured by C. R. Stauffer and C. R. Schroyer. Base elevation 612 feet.

| | ft | in | ft | in |
|---|---|---|---|---|
| 29. Covered interval to the top of the hill, slightly above the 1000-foot contour | 10 | 0 | 396 | 3 |
| 28. Limestone, bluish-gray, hard, fossiliferous; associated with calcareous gray shale. NINEVEH | 1 | 10 | 386 | 3 |
| 27. Covered interval | 17 | 0 | 384 | 5 |
| 26. Shale, gray, arenaceous | 3 | 2 | 367 | 5 |
| 25. Sandstone, buff to yellowish, rather soft, micaceous | 2 | 8 | 364 | 3 |
| 24. Covered interval | 10 | 0 | 361 | 7 |
| 23. Shale, purplish-red; limestone nuggets and a slight fire clay at the base | 3 | 10 | 351 | 7 |
| 22. Shale, red; with streaks of gray to buff | 16 | 0 | 347 | 9 |
| 21. Shale, red and gray to yellowish, weathered | 21 | 4 | 331 | 9 |
| 20. Sandstone, gray, rather fine-grained massive, micaceous (this was once quarried for grindstones). JOLLYTOWN | 23 | 4 | 310 | 5 |
| 19. Covered interval | 19 | 10 | 287 | 1 |
| 18. Shale, red; with gray and yellow streaks to the base of the tank above the quarry | 18 | 0 | 267 | 3 |
| 17. Shale, sandy buff, rather compact | 9 | 2 | 249 | 3 |
| 16. Sandstone, blue to buff, medium-grained, micaceous (present grindstone horizon at Constitution). HUNDRED of the West Virginia reports | 19 | 5 | 240 | 1 |
| 15. Covered interval | 31 | 1 | 220 | 8 |
| 14. Shale, red, argillaceous | 1 | 8 | 189 | 7 |
| 13. Sandstone, buff, fine-grained, rather massive, micaceous | 7 | 0 | 187 | 11 |
| 12. Shale, red, argillaceous | 14 | 6 | 180 | 11 |
| 11. Sandstone, gray to buff, nodular, calcareous; in several layers | 2 | 3 | 166 | 5 |
| 10. Shale, red- and gray-mottled | 2 | 4 | 164 | 2 |
| 9. Sandstone or sandy shale, gray, rather thin-bedded | 3 | 8 | 161 | 10 |
| 8. Sandstone, gray to buff, micaceous | 1 | 4 | 158 | 2 |
| 7. Shale, yellow-gray, soft, micaceous, sandy | 0 | 4 | 156 | 10 |
| 6. Sandstone, gray to buff, medium- to fine-grained, massive, micaceous (has been quarried extensively for grindstones). UPPER MARIETTA | 29 | 6 | 156 | 6 |
| 5. Shale, red, partly covered. CRESTON REDS | 69 | 0 | 127 | 0 |
| 4. Sandstone, gray, massive, micaceous; laminated and becoming shaly on weathering; lower contact irregular; and the sandstone may rest on blue to gray shale. LOWER MARIETTA | 32 | 0 | 58 | 0 |
| 3. Covered interval | 5 | 0 | 26 | 0 |
| 2. Coal blossom. WASHINGTON | 1 | 0 | 21 | 0 |
| 1. Covered interval to the level of the Baltimore & Ohio Railroad track at Constitution Station | 20 | 0 | 20 | 0 |

# SUBSURFACE STRATIGRAPHY

## INTRODUCTION

With the exception of a single occurrence of the Skelley(?) and Ames limestones above drainage on the crest of the Newell Run Anticline, rocks below the mid-Conemaugh are restricted to the subsurface (fig. 17) in Washington County. The description and discussion of units from the Lower Silurian Tuscarora (Albion) Sandstone to the mid-Conemaugh Skelley(?) limestone are based on 56 sets of well-sample cuttings. These samples include 40 suites from Washington County and 16 from adjacent counties and from West Virginia. The majority of these samples were collected from wells drilled to the Berea (Mississippian) or younger strata, but 17 were from wells drilled to the Oriskany (Devonian) and 7 from wells to the Tuscarora. The authors described all or portions of 48 sets of samples and

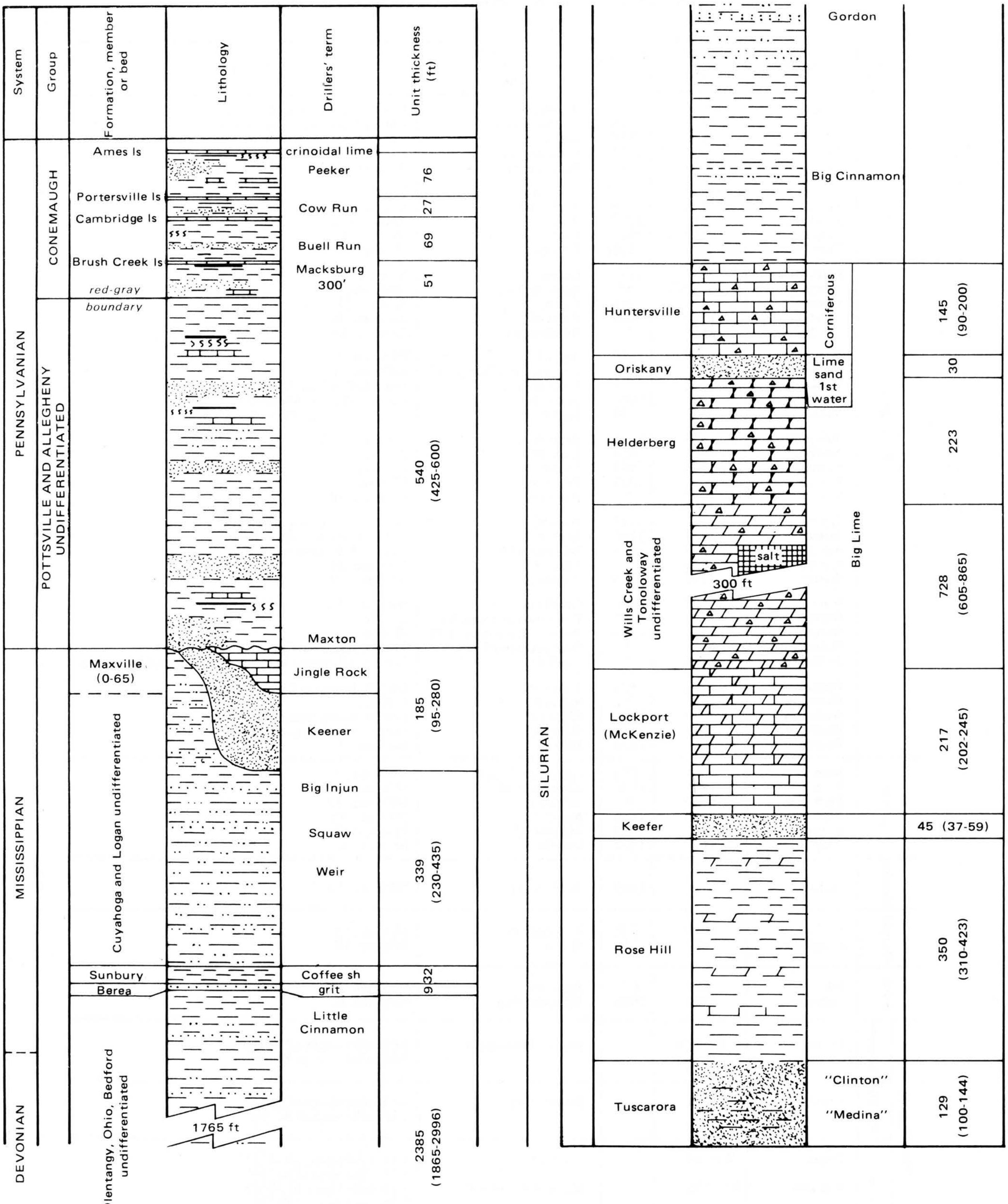


FIGURE 17.–Generalized stratigraphic column for the subsurface rocks of Washington County, Ohio.

TABLE 2.—*Well samples studied in Washington County, Ohio, and adjacent areas*

| County | Township | Permit no. | Sample no. | Lease name and well no. | Location |
|---|---|---|---|---|---|
| Washington | Adams | 210 | 108 | Augenstein #1 | Lot 49, Bear Creek Allotment |
| | Adams | 2531 | 978 | Pottmeyer #1 | Lot 26, Cats Creek Allotment |
| | Adams | 2560 | 979 | Ball #1 | Lot 8, Big Run Allotment |
| | Adams | 2581 | 1002 | Beardsley #1 | Lot 21, Cats Creek Allotment |
| | Barlow | 2756 | 1147 | McIntire #1 | NE¼ sec. 24 |
| | Belpre | 1311 | 577 | Lamp #1 | Lot 66 |
| | Belpre | 1529 | 492 | Walker #1 | Lot 64 |
| | Dunham | 2821 | 1207 | Ross #1 | NW¼ sec. 16 |
| | Grandview | 2653 | 1021 | Fauble Heirs #1 | SE¼ sec. 6 |
| | Grandview | | 326F | Edwards #1 | SW¼ sec. 18 |
| | Independence | 2835 | 1157 | Cullen #1 | SE¼ sec. 36 |
| | Independence | C-0027-7-1 | *[1] | Knowlton #1 | NW¼ sec. 10 |
| | Lawrence | 359 | 168 | Hill #1 | SE¼ sec 25 |
| | Liberty | 1914 | 633 | Scott #1 | NE¼ sec. 20 |
| | Ludlow | 2875 | * | Ronshausen #2 | SE¼ sec. 10 |
| | Marietta | 369 | 1190 | Hall #1 | NE¼ sec. 17 |
| | Marietta | | 274 | International Derrick #1 | NW¼ sec. 36 |
| | Muskingum | 2572 | 1088 | Deist Heirs #1 | Lot 32, Rainbow Allotment |
| | Muskingum | 2618 | 1007 | Stacy #1 | Lot 2, Rainbow Allotment |
| | Muskingum | 2642 | 1134 | Burkey #1 | Lot 9, Wiseman's Bottom Allotment |
| | Newport | 2824 | 1145 | Riggs *et al.* #3 | NW¼ sec. 21E |
| | Newport | 2887 | 1553 | Link #K1 | SE¼ sec. 31 |
| | Palmer | 303 | 481 | Stollar #1 | Lot 823 |
| | Palmer | 2605 | 1087 | Derby #2 | NE¼ sec. 26 |
| | Palmer | 2630 | * | Stover #1 | NE¼ sec. 26 |
| | Salem | 2760 | 1115 | Haas #1 | Lot 72, Bear Creek Allotment |
| | Salem | 2834 | 1146 | Lent #1 | Lot 164, Duck Creek Allotment |
| | Salem | 2849 | 1618 | Weppler #1A | Lot 53, U.S. Reverted Lands |
| | Warren | 853 | 5 | Edgar #1 | NE¼ sec. 24 |
| | Warren | 2238 | 50 | Ammon #1 | NE¼ sec. 29 |
| | Warren | 2582 | 1000 | Gustke *et al.* #1 | NW¼ sec. 14 |
| | Warren | 2761 | 1137 | Constitution Stone #1 | Lot 271 |
| | Warren | 2766 | 1106 | Braden Development #1 | SE¼ sec. 6 |
| | Waterford | 2668 | * | Smith-Kearn #1 | Lot 59, Rainbow Creek Allotment |
| | Waterford | 2706 | * | Land #1 | Lot 13, Allotment between Rainbow and Waterford |
| | Watertown | 1552 | 557 | Farley #1 | Lot 29, Rainbow Creek Allotment |
| | Watertown | 2619 | * | Miller #1 | Lot 802 |
| | Watertown | 2649 | 1107 | Milner #1 | Lot 19, South Branch Allotment |
| | Watertown | 2745 | 1116 | Miller #2 | Lot 21, South Branch Allotment |
| | Wesley | 2681 | 1074 | Pahl #1 | SW¼ sec. 2 |
| Athens | Bern | 1041 | 552 | Armadale Coal #25 | NW¼ sec. 7 |
| | Bern | 1404 | 1026 | Christman #1 | SE¼ sec. 26 |
| | Bern | 1482 | * | Antle #4 | NW¼ sec. 32 |
| | Bern | 1498 | 1855 | Kasler #2 | SW¼ sec. 33 |
| | Rome | 1366 | 905 | Skinner #1 | Fraction 17 |
| | Troy | 1426 | 1073 | Dunfee #1 | NE¼ sec. 4 |
| Monroe | Jackson | 1594 | 1049 | A. R. A. #1 | NW¼ sec. 18 |
| Morgan | Marion | 1010 | 982 | Bowman #1 | SE¼ sec. 16 |
| | Meigsville | 602 | 210 | Murrey #1 | SE¼ sec. 12 |
| Noble | Elk | 917 | 607 | Pabst #1 | NW¼ sec. 15 |
| | Jackson | 1195 | 1004 | Rubrake #1-S | NE¼ sec. 36 |
| West Virginia, Pleasants | Union | Pl-612R | | Ben #5 (Rosalene) | 3.02 miles south of 39°30′ 0.68 miles west of 81°05′ |
| West Virginia, Ritchie | Grant | Rit-941 | | Rinehart #1 | 4.51 miles south of 39°20′ 1.20 miles west of 81°10′ |
| West Virginia, Wood | Tygart | Woo-99 | | Cook #1 | 5.16 miles south of 39°15′ 3.63 miles west of 81°30′ |
| | Williams | Woo-172 | | Big Run Oil #8876 | 5.18 miles south of 39°25′ 2.38 miles west of 81°25′ |
| | Walker | Woo-351 | | Hope Natural Gas #9634 | 5.4 miles south of 39°20′ 1.14 miles west of 81°15′ |

[1] Sample description or geolog only.

used the descriptions of other workers in 8 instances. Table 2 lists the wells for which sample data are available and figure 18 shows the geographic locations of the sample suites from Washington County.

In addition to well samples, a few thousand drillers' records were available for study. However, data from these records were used only in the study of the Berea Sandstone and older units. A substantial number of gamma ray-neutron logs were also available and were particularly helpful in study of the sequence between the Berea Sandstone and the base of the Pennsylvanian strata.

## SILURIAN SYSTEM

### GENERAL STATEMENT

The Silurian as well as the Lower and Middle Devonian rocks of Washington County are sufficiently different from their counterparts on the outcrop to the west that Ohio terminology is not deemed appropriate. Pending further study, West Virginia terminology is considered more applicable to the immediate Washington County area (see Woodward, 1959a, and Shearrow, 1957).

Shearrow (1957) and Horvath (1964) have constructed subsurface cross sections, involving Silurian strata, into or across Washington County. However, further detailed regional subsurface studies must be made for complete understanding of the Silurian. Three sets of samples through the Silurian System in Washington County were available, as well as published descriptions for three localities closely adjacent to the county in both Ohio and West Virginia. The following discussion and the cross section of plate 7 are based solely on these six sets of data.

### DESCRIPTION OF UNITS

#### Tuscarora Sandstone

The lowest unit penetrated by drilling to date in Washington County is the Tuscarora Sandstone, which is correlated by Shearrow (1957, p. 5) with the Albion (Medina). Drillers' names for the sandstone of this interval are the "Clinton" and "Medina" sands. An average thickness of 129 feet is recorded for the formation. The red shales and siltstones of the underlying Juniata (Queenston) mark the base of the unit.

The Tuscarora in this region is mostly a tightly cemented very fine-grained white sandstone broken by thin to thick shale interbeds. The unit tends to be shaly in the lower portion, has a few clean sand lenses in the basal and middle portions, and is relatively clean sand in the upper portions. Some red sandstone has been reported in the upper

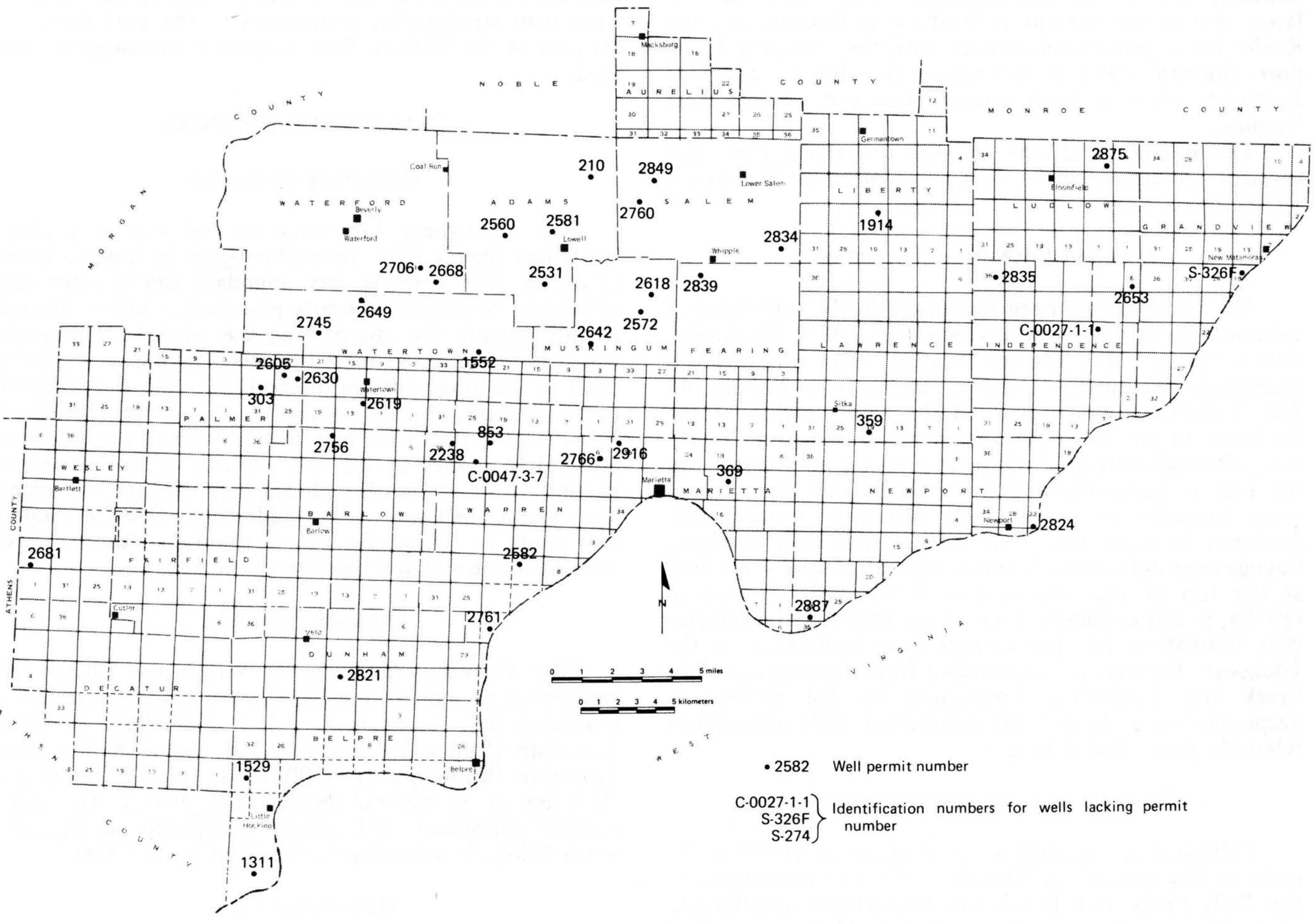


FIGURE 18.–Geographic locations of well samples studied in Washington County, Ohio.

portion of the unit.

The top of the Tuscarora is gradational with the base of the overlying Rose Hill Formation. The contact has been drawn where the dominant lithology changes from sandstone to shale.

### Rose Hill Formation

The Rose Hill Formation in this area averages 350 feet in thickness and is represented by red and green or gray shale and siltstone interbedded with thin stringers of fossiliferous dolomitic limestone. Some sand may be present in the formation, but not as a major portion of the unit. The contact between the Rose Hill and overlying Keefer Sandstone is sharp and readily picked from either samples or gamma ray-neutron logs. Where the Keefer is absent or poorly defined, a gradational boundary exists between the Rose Hill and the Lockport.

### Keefer Sandstone

A limy or dolomitic well-cemented fine-grained sand is found in the position of the Keefer Sandstone in all 6 wells used to construct plate 7. The formation is thickest and best defined in the eastern part of the county, but becomes indistinct in the westernmost two wells. The Keefer is normally overlain by the Rochester Shale; however, the latter unit is not present in Washington County, and the Keefer has a gradational contact with the overlying Lockport. Horvath (1964, p. 53) reports the absence of typical Rochester Shale in both eastern Ohio and western West Virginia.

The Keefer Sandstone and the underlying Rose Hill together are equivalent to the Clinton group of Shearrow's 1957 cross section.

### Lockport (McKenzie) Formation

The Lockport has been recognized in the subsurface of eastern Ohio by many workers (Shearrow, 1957, Woodward, 1959a, Ulteig, 1964). The unit is rather uniform in thickness throughout Washington County, ranging from 200 to 245 feet. Limestone was present in the basal portion of the Lockport in all the samples from the Washington County area, although Ulteig (1964, p. 16) reports no limestone in the unit in northeastern Ohio. Shale is quite abundant at some localities in the county, although normally the Lockport is a less shaly and cleaner unit than overlying Cayugan-age dolomites. A minor amount of sand was found at the top of the formation in a few wells: Woodward (1959a, p. 20) considers this zone to represent the Williamsport Formation, but the authors have included it in the Lockport. The unit is distinguished from the overlying Wills Creek and Tonoloway Formations by the absence of evaporites and a change from argillaceous, shaly dolomite to relatively pure, clean dolomite.

### Wills Creek and Tonoloway Formations

Following the general usage of Shearrow (1957, p. 7), rocks of Cayugan age in Washington County are assigned to the Wills Creek and Tonoloway Formations undifferentiated. These rocks comprise an interbedded sequence of dolomite, dolomitic limestone, anhydrite, salt, and shale.

The dolomite and dolomitic limestones are generally light to dark brown or gray and range in texture from microcrystalline to saccharoidal. Evaporites are common throughout this sequence but salt is found only in the eastern portion of the county (pl. 7, fig. 39). The thickness of the combined formations ranges from 605 to 865 feet and averages 728 feet.

The dolomitic nature of the carbonates has long been a useful criterion in distinguishing this sequence from the overlying cherty Helderberg Limestone.

## DEVONIAN SYSTEM

### GENERAL STATEMENT

The Devonian rocks of Washington County differ considerably from their correlatives on the outcrop in central and northern Ohio. The sequence from the top of the Huntersville Chert to the base of the Berea Sandstone includes the Olentangy Shale and the Ohio Shale (subdivided in northern Ohio into the Huron, Chagrin, and Cleveland Shales) of Devonian age and the Bedford Shale of Mississippian age. With one exception, none of these formations could be distinguished in the subsurface of Washington County on the basis of well cuttings, and in this report the entire sequence is treated as a unit.

The Middle Devonian rocks (Helderberg Limestone to Huntersville Chert) of the county are sufficiently different from their stratigraphic equivalents to the west that, as in the case of the Silurian, West Virginia terminology has been used.

### DESCRIPTION OF UNITS

### Helderberg Limestone

The Helderberg Limestone in this area is a microcrystalline cherty light- to medium-gray to buff to brown limestone. The chert is very abundant and in some cases appears to be present as nearly pure beds or lenses. The unit is only slightly less cherty than the younger Huntersville, which it resembles in most respects. There is generally less chert in the lower portion of the Helderberg, and Shearrow (1957) recognizes this portion as the Keyser Limestone. However, the beds that may be assignable to the Keyser are not clearly defined by the data available to the authors; this portion of the section is included here with the Helderberg. The average thickness of the Helderberg is 223 feet, and the unit seems to follow the normal trend for this area, being thickest in the east and thinning to the west.

### Oriskany Sandstone

The Oriskany Sandstone in Washington County is a well-sorted angular to rounded fine- to coarse-grained white sandstone that ranges from 3 feet in thickness in Wesley Township (Pahl #1, P-2681) to 103 feet in Independence Township (Knowlton #1, C-0027-1-1) (pl. 7). The average thickness in 30 wells is slightly over 29 feet. The unit is slightly calcareous and almost completely disaggregates when drilled. It is overlain by the Huntersville Chert.

### Huntersville Chert

The Huntersville Chert in Washington County is represented by a very cherty microcrystalline light-gray to buff or brown limestone with zones of nearly pure chert. White to bluish-gray to brown chert may make up to 90 percent of the samples. The unit is broken by a few thin calcareous cherty shale partings. Thin sandstone partings are also present near the base and in places the limestone is slightly sandy. The unit, the "Corniferous," represents the top of the driller's "Big Lime," and thickens rapidly to the east from 90 feet in Wesley Township (Pahl #1, P-2681) to 200 feet in Independence Township (Knowlton #1, C-0027-1-1) (fig. 19; pl. 8). The upper contact with the Ohio Shale is sharp and is readily recognizable by the change from limestone to black shale.

The Tioga Bentonite is present throughout the county as a soft micaceous light-brown shale at or near the top of the Huntersville. The exact thickness and position of the Tioga is somewhat uncertain, but the samples suggest the unit is quite thin, possibly on the order of only 1 foot, and is located very near the base of the Ohio Shale. The bentonitic character of the Tioga has been verified by X-ray analysis (D. K. Webb, oral communication).

Structure contours drawn on the top of the Huntersville (fig. 20) show a rather uniform east to southeast dip of approximately 57 feet per mile as determined from elevations at the Pahl #1 (P-2681), the Stollar #1 (P-303), and the Constitution Stone Co. #1 (P-2761) wells in Wesley, Palmer, and Warren Townships, respectively.

Ohio Shale and adjacent beds

Although the member and formation distinctions of the crop could not be carried into the subsurface, the sequence of the Ohio Shale and adjoining beds can generally be divided roughly into lower, intermediate, and upper zones on the basis of color and gross lithology. The lower one-quarter to one-third of the sequence is composed primarily of dark-gray to brownish to black pyritic shale. The upper three-quarters to two-thirds is characterized by interbedded predominantly light- to medium-gray shales and siltstones. Some of the siltstone ranges from brown to reddish brown and grades into fine-grained sandstone. A few lenses of limestone and calcareous siltstone are present also. The contact between the lower dark shale zone and the upper light-colored shale and siltstone is not sharp; commonly an intermediate third zone composed of a combination of both types of material separates the lower and upper zones. Spores of the *Tasmanites* type are present throughout the sequence, but are most abundant in the lower zone. Where spores are extremely abundant, they impart a brownish-amber cast to the shale.

The sequence of the Ohio Shale and adjoining beds ranges in thickness from just under 1,900 feet in Wesley Township (Pahl #1, P-2681) to over 3,300 feet in Independence Township (Knowlton #1, C-0027-1-1), showing a

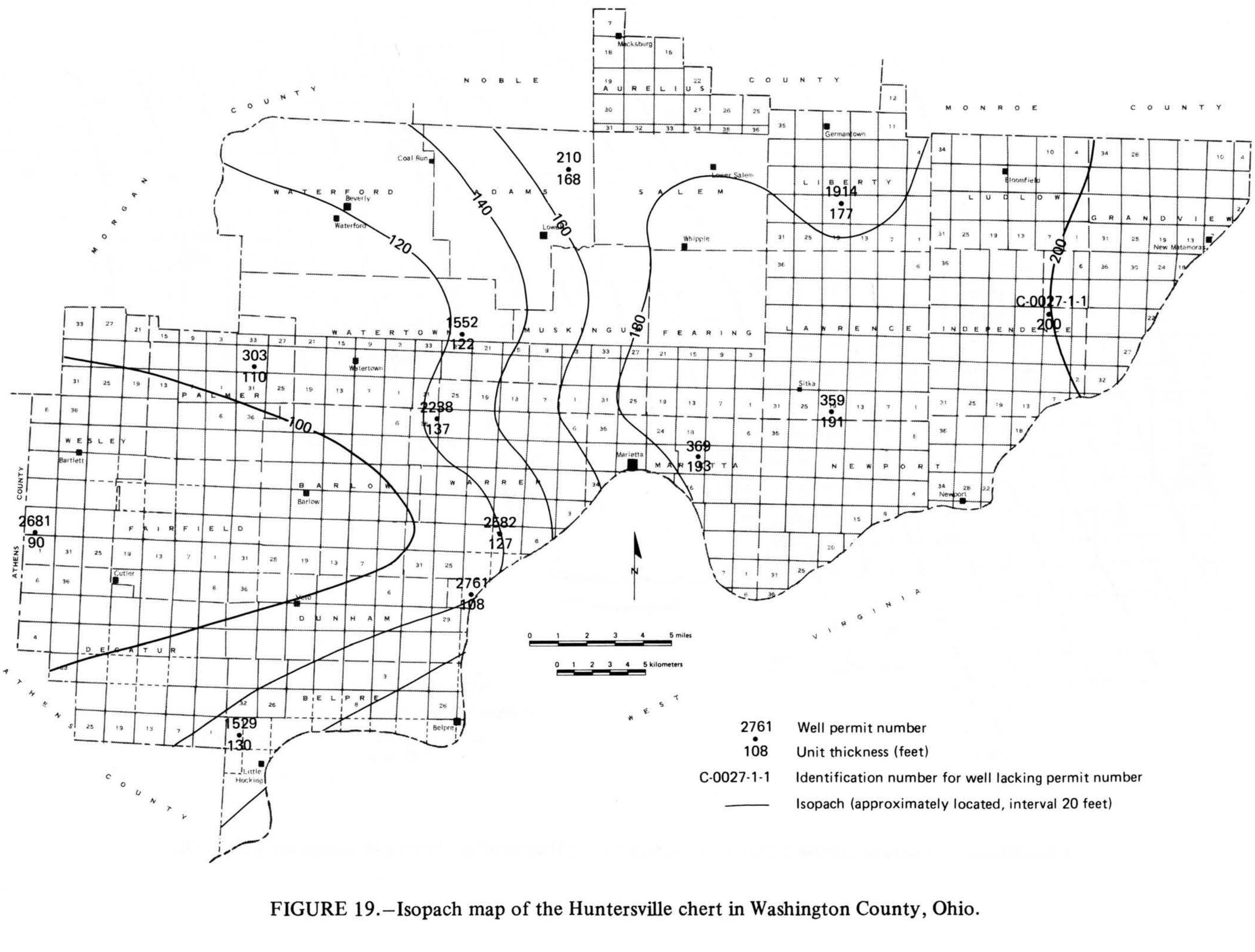


FIGURE 19.—Isopach map of the Huntersville chert in Washington County, Ohio.

uniform eastward thickening (fig. 21). The individual zones all thicken eastward, maintaining the same relative thickness across the county.

An interesting aspect of the section is the presence of a previously unreported bentonitic shale which was discovered in the lower portion of the sequence, substantially above the Tioga Bentonite. This zone, here informally called the Belpre bentonite, is a very thin (probably less than a foot) coarsely micaceous soft brown shale or siltstone. This unit was first noted in Belpre Township in the Lamp #1 (P-1311). It was subsequently identified in many other wells throughout the county (fig. 22) and is present from 60 feet (Pahl #1, Wesley Township, P-2681) to 236 feet (Scott #1, Liberty Township, P-1914) above the top of the Huntersville Chert, reflecting the persistent eastward-thickening trend in the county. In the laboratory, X-ray diffraction patterns of this bentonite compare favorably with those of the lower Tioga Bentonite (D. K. Webb, oral communication).

A single well on the extreme western edge of the county revealed the red shale of the Bedford, which is persistently found overlying the Ohio Shale in the counties to the west. Ten feet of medium-gray and reddish-brown shale was found about 15 feet below the Berea in Wesley Township (Pahl #1, P-2681). A very slight reddish tinge was noted in one or two other wells in the northwestern part of the county. These few data are in agreement with Pepper and others' (1954) mapping of the Red Bedford Delta.

## MISSISSIPPIAN SYSTEM

### GENERAL STATEMENT

The Mississippian units recognized in the subsurface in Washington County include the Berea Sandstone, Sunbury Shale, Logan and Cuyahoga Formations undifferentiated, and Maxville Limestone. The Bedford Shale, at the base of the Mississippian, cannot be differentiated from the underlying Ohio Shale and is discussed with that unit. The thickness of the post-Bedford Mississippian, based on the interval from the base of the Berea Sandstone to the top of the Maxville Limestone, ranges from 575 feet in the western part of the county to 650 feet in the east.

### DESCRIPTION OF UNITS

#### Berea Sandstone

The Berea Sandstone is present throughout eastern

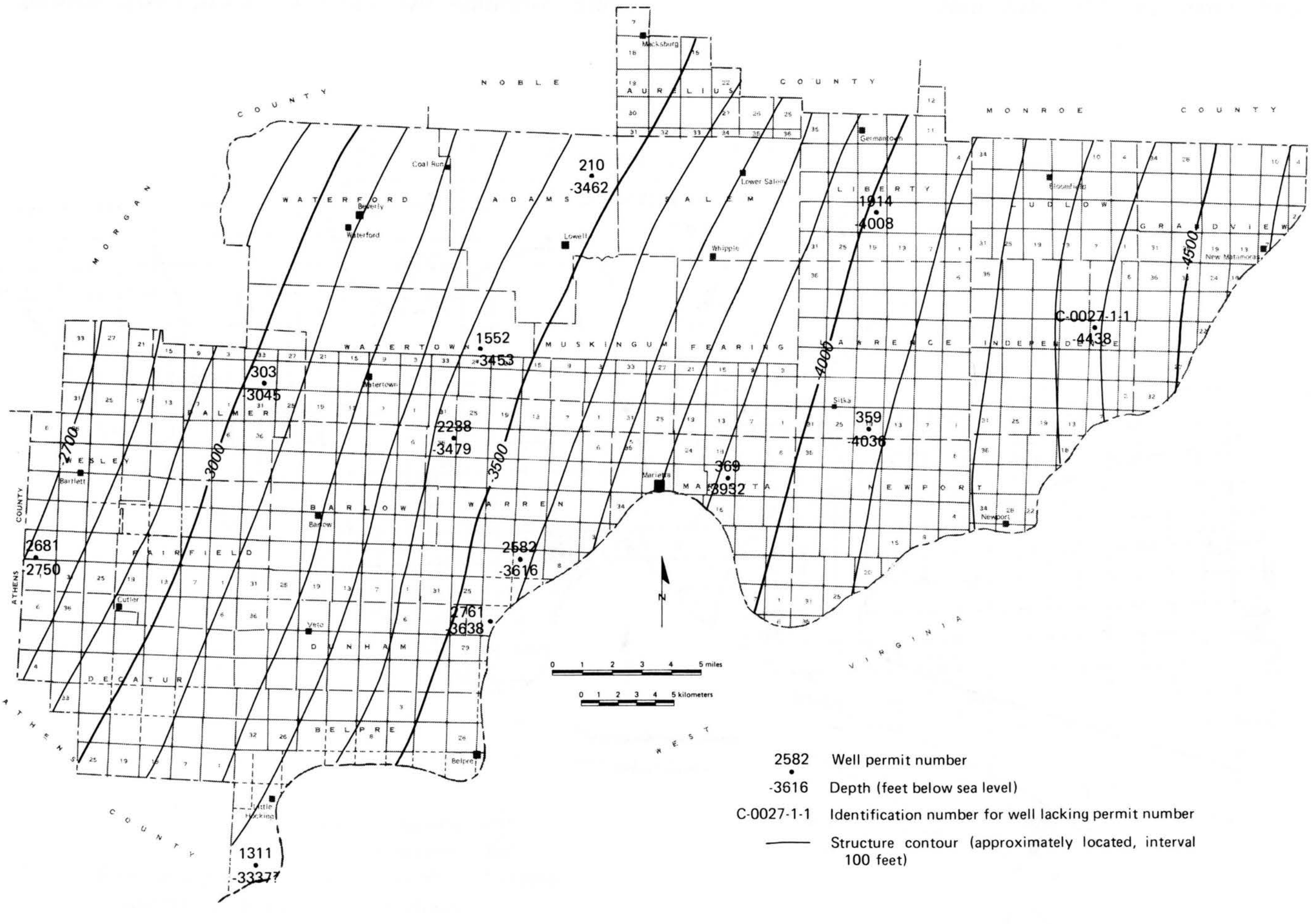


FIGURE 20.—Structure contours drawn on the top of the Huntersville chert in Washington County, Ohio.

Ohio. Pepper and others (1954, p. 34) stated that

> the Berea sand may be traced underground by means of numerous well records and is recognizable in the subsurface as an almost continuous sand body over thousands of square miles of eastern Ohio, western Pennsylvania, western West Virginia, and northeastern Kentucky.

They stated further that

> except in local areas . . . no other persistent sands are found near the horizon of the Berea.

These authors (p. 74) gave a detailed interpretation of the geology of the Berea throughout the Appalachian Basin; they considered that the Berea sediments in the Washington County area

> were spread along the eastern edge of the Ohio Bay as shore-line deposits and a thin marine pavement.

In Washington County the Berea is represented by a persistent pyritic fine- to very fine-grained light-gray to white to buff sandstone or siltstone. In places the unit is sparsely fossiliferous and slightly calcareous. The greatest thickness observed in 19 well samples suites was about 15 feet, and the average thickness was 9 feet. However, scattered local thicknesses on the order of 25 feet have been reported by drillers. The light-colored Berea is easily distinguished from the overlying black Sunbury Shale, but is much less readily separated from the lithologically similar siltstones of the underlying Bedford Shale. In places it is quite difficult to draw the base of the Berea. The Berea sand has been extensively probed throughout the county in the search for oil and gas, and a more complete discussion of this aspect will be found in the chapter on mineral resources.

## Sunbury Shale

The Sunbury Shale in Washington County is a *Lingula*-bearing carbonaceous black shale averaging about 32 feet in thickness. It is found almost everywhere throughout the county and is an excellent stratigraphic marker, easily identified in well samples and by its sharp increase in gamma radiation on gamma ray-neutron logs. Most drillers recognize this unit, which they term "Coffee Shale." It is easily distinguished from the medium-gray shales of the overlying Cuyahoga by its distinctive black color.

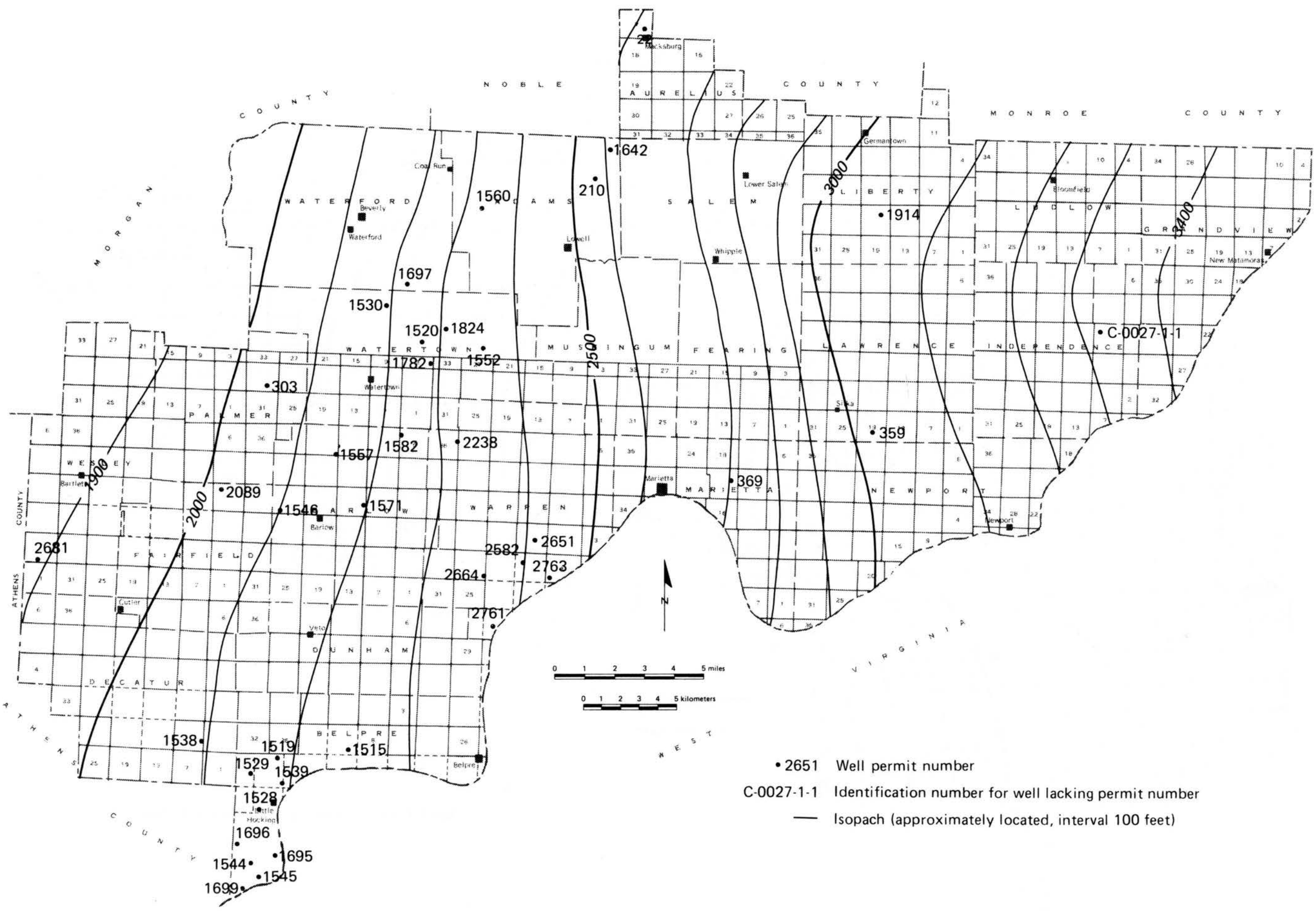


FIGURE 21.—Isopach map of the interval from the top of the Huntersville chert to the base of the Berea Sandstone, Washington County, Ohio.

Cuyahoga and Logan Formations undifferentiated

The contact between the Cuyahoga and Logan Formations in Ohio has traditionally been placed at the Berne Conglomerate, which has been considered the uppermost member of the Cuyahoga by some workers and the lowermost member of the Logan by others. However, the Berne cannot be recognized in Washington County.

Both the Cuyahoga and Logan Formations have been divided by Hyde (1953) and Holden (1942) into a complex series of facies which have been given combination geographic-lithologic designations. These facies have been further subdivided into members which may be restricted to a single facies or may be traced into adjacent facies. This work has been confined to the area of outcrop and, as pointed out by Holden (1942, p. 34), correlations have been made mostly on the basis of stratigraphic position and succession and to some extent on faunal evidence. There has been no serious work on this sequence in the subsurface and the authors do not attempt to apply the terminology of the outcrop in Washington County.

The Cuyahoga and Logan Formations in Washington County consist of from 475 to 640 feet of sandstone, siltstone, and shale which have been divided arbitrarily by the authors into two "members," the "lower" and "upper," which may in fact represent only the Cuyahoga Formation. The thickness and lithology of the sequence agree well with the thickness and lithology of the Cuyahoga on the outcrop, particularly of the Toboso facies of Hyde (1953), Holden (1942), and Franklin (1961).

The thickness of the undifferentiated Cuyahoga-Logan in the Washington County area averages about 531 feet. This is within the range reported by K. R. Walker (1962, p. 108, fig. 2), who showed the Lower Mississippian in this part of Ohio to be between 500 and 600 feet thick and to thicken to the northwest. Haught (1955, p. 2) also called attention to this thickening trend in the West Virginia counties bordering the area:

> Unlike all groups above it, the Pocono [Cuyahoga and Logan undifferentiated of this report] thickens *northwestward* across these counties, from 450 feet to well over 500 feet.

The data available in the Washington County area (fig. 23) are inconclusive with respect to a northwest-thickening trend; thickness variations are most probably largely attributable to post-Mississippian erosion.

The "lower member" of the undifferentiated Cuyahoga and Logan Formations is comprised of a monotonous series of interbedded very fine-grained light- to dark-gray siltstones

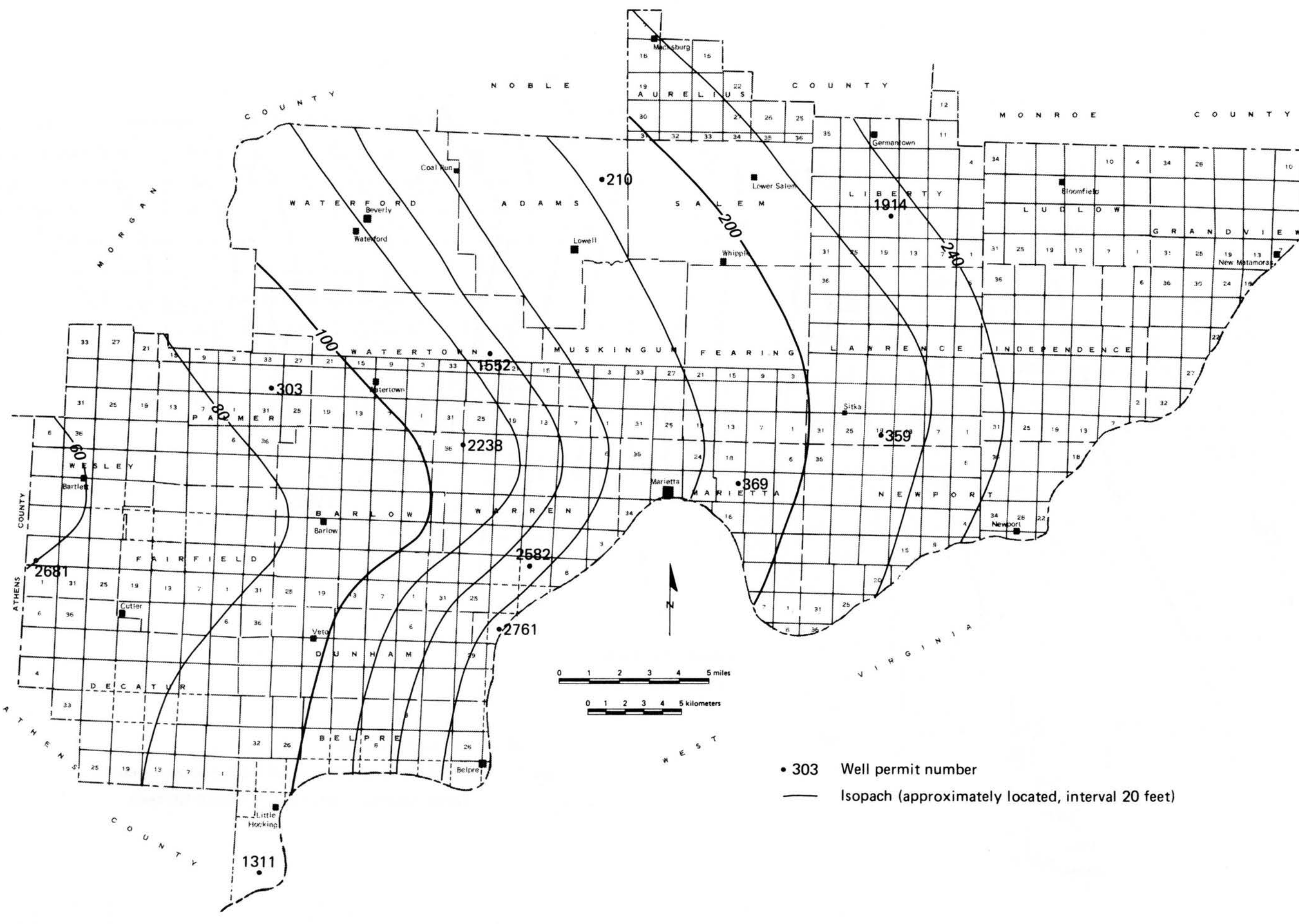


FIGURE 22.–Isopach map of the interval from the top of the Huntersville chert to the Belpre bentonite, Washington County, Ohio.

and shales and very fine-grained silty sandstones. Beds of this "member" grade subtly from one lithology to another with no readily apparent order. The "lower member" averages 336 feet in thickness and is thinnest where the overlying "upper member" is thickest (fig. 23, pl. 8). Marine fossils are found throughout the "member" and small amounts of clay ironstone, probably from concretions, are commonly found in the samples.

The "upper member" consists of a clean fine-grained to conglomeratic weakly cemented white or buff sandstone. It ranges from 95 to 290 feet in thickness, with a few thin 5- to 10-foot shale breaks. This "member," the "Big Injun" of the drillers, commonly completely disaggregates when drilled. Where overlain by the Maxville Limestone the upper few feet of the unit is commonly calcareous and probably represents the drillers' "Keener" sand. Where a shale break occurs near the base of the "member," the term "Squaw" sand is applied by drillers to the bottom of the unit. Shale breaks dividing the "upper member" into the "Keener," "Big Injun," and "Squaw" sequence seem to be confined roughly to the easternmost six townships of the county.

The "upper member" is consistently thickest along a northwest-southeast line from central Adams Township to the Marietta-Newport Township line at the Ohio River. Although there are few data available in the western portion of the county, it is apparent that the upper member becomes shaly and less distinctive to the west. This trend is noticeable in western Watertown and northern Palmer Townships and is quite obvious in eastern Athens and Morgan Counties, where the "upper member" is indistinguishable from the "lower member" (pl. 8).

## Maxville Limestone

Lamborn (1945, p. 14) indicated that the Maxville (Greenbrier of West Virginia) is present over much of eastern Washington County, but is essentially nonexistent in the western region. New data, particularly from well samples not available to Lamborn, have enabled the authors to make a new interpretation of the distribution of this unit: erosional remnants are found in both the eastern and western parts of the county (fig. 24, pl. 9A, B). Andrews (1869, p. 83), who named the Maxville, recognized the patchy distribution of the unit. He originally attributed this nonpersistent character to lack of deposition rather than to erosion, but later (1878, p. 821-822) suggested that it was possibly the result of erosion. Subsequent workers have shown that both the upper and lower contacts of the Maxville are disconform-

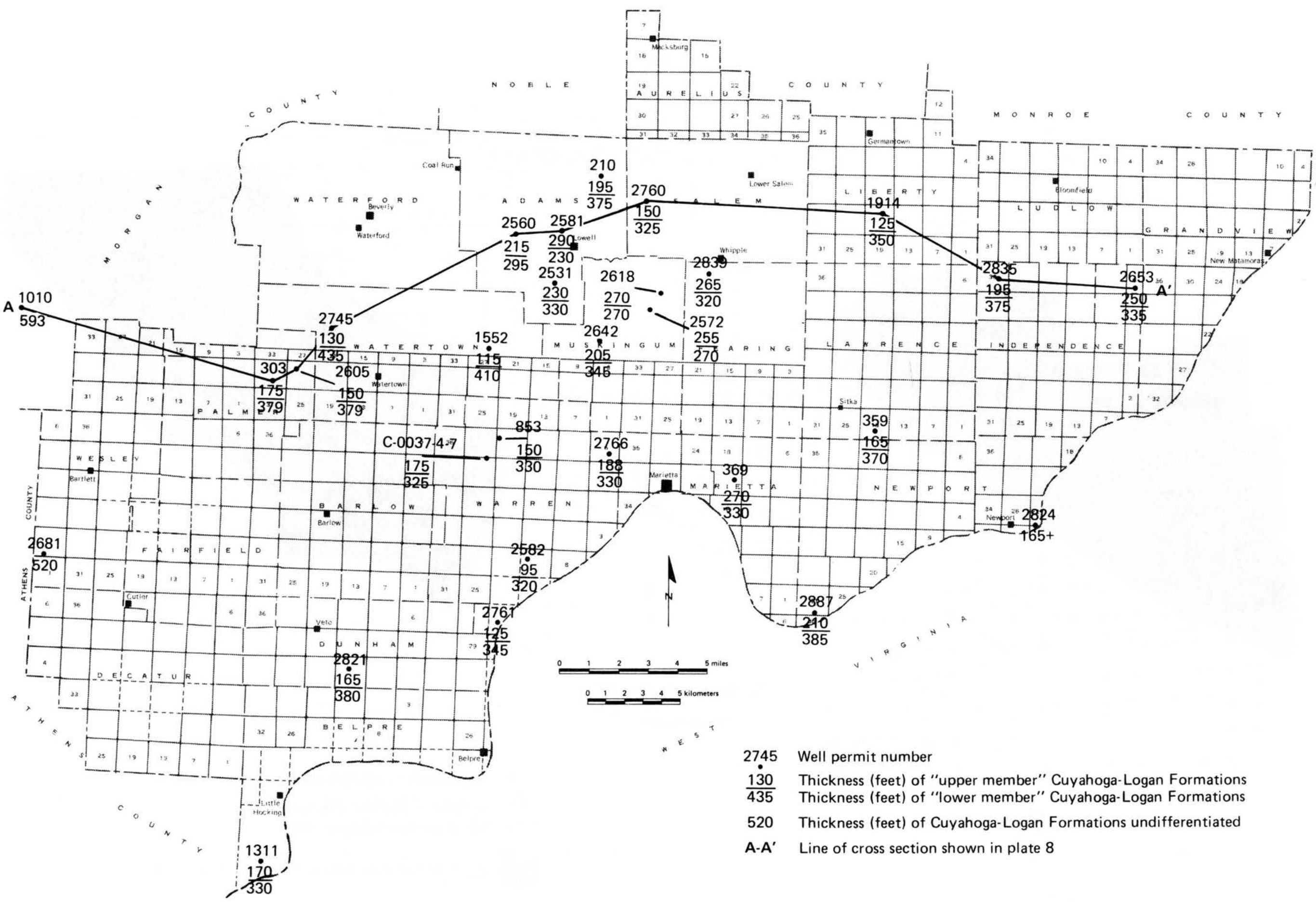


FIGURE 23.–Thicknesses of the "upper member" and "lower member" of the Cuyahoga-Logan Formations in Washington County, Ohio, and line of cross section for plate 8.

able. Rittenhouse (1949, p. 1707, 1709) summed up:

> In the northwest part of West Virginia and in all of Pennsylvania and Ohio where the [Maxville] occurs, it rests unconformably on Lower Mississippian sandstones and shales. . . . In northeastern West Virginia and southeastern Ohio where the Mauch Chunk has been removed by erosion, or was never deposited, sands of the Pottsville formation lie on the eroded surface of the Greenbrier.

The Maxville in eastern Washington County is represented by an oolitic sandy amber to tan to tannish-gray limestone which is as much as 65 feet thick in Independence Township (Cullen #1, P-2835). The sandy and oolitic zones seem to be confined to the lower one-half to two-thirds of the unit; however, because of the irregular thickness, correlation of individual zones was not attempted.

Where present in the western portion of the county, this unit is somewhat thinner than in the east. Fifty-two feet was the maximum thickness observed by the authors in the west (Derby #2, P-2605, Palmer Twp.), although as much as 60 feet has been reported. Five sites in western Washington County averaged only 24 feet in thickness, whereas five samples in the east averaged 44 feet. The distribution, thickness, and subsea elevations of the Maxville are shown in figure 24; a discussion of the economic aspects of the unit will be found in the chapter on mineral resources.

## MISSISSIPPIAN-PENNSYLVANIAN BOUNDARY

The Mississippian-Pennsylvanian systemic boundary in Ohio is placed at the top of the Maxville Limestone. However, in most of the state the Maxville has been removed by erosion, and clastic basal Pennsylvanian rocks of the Pottsville Group rest disconformably on clastic Mississippian rocks. In Washington County where the Maxville Limestone is absent the uppermost Mississippian is generally composed of clean fine-grained to conglomeratic quartz sandstone or very fine-grained light- to dark-gray siltstone interbedded with shale and silty sandstone.

The overlying Pottsville Group, which in well cuttings can generally be readily distinguished from the underlying Mississippian, is characterized by a repetitive sequence of carbonaceous shales and dirty sandstones, and thin coals, limestones, and clay ironstones. In some places the lowermost Pottsville sands are very similar to the underlying Mississippian sands. Where this situation exists, it is somewhat more difficult to establish the exact contact, but the authors feel that careful attention to the samples generally allows a separation to be made. Chert fragments derived from weathering and erosion of the Maxville Limestone are found in a few places in the basal Pottsville sandstones and serve to mark the systemic boundary. The uppermost

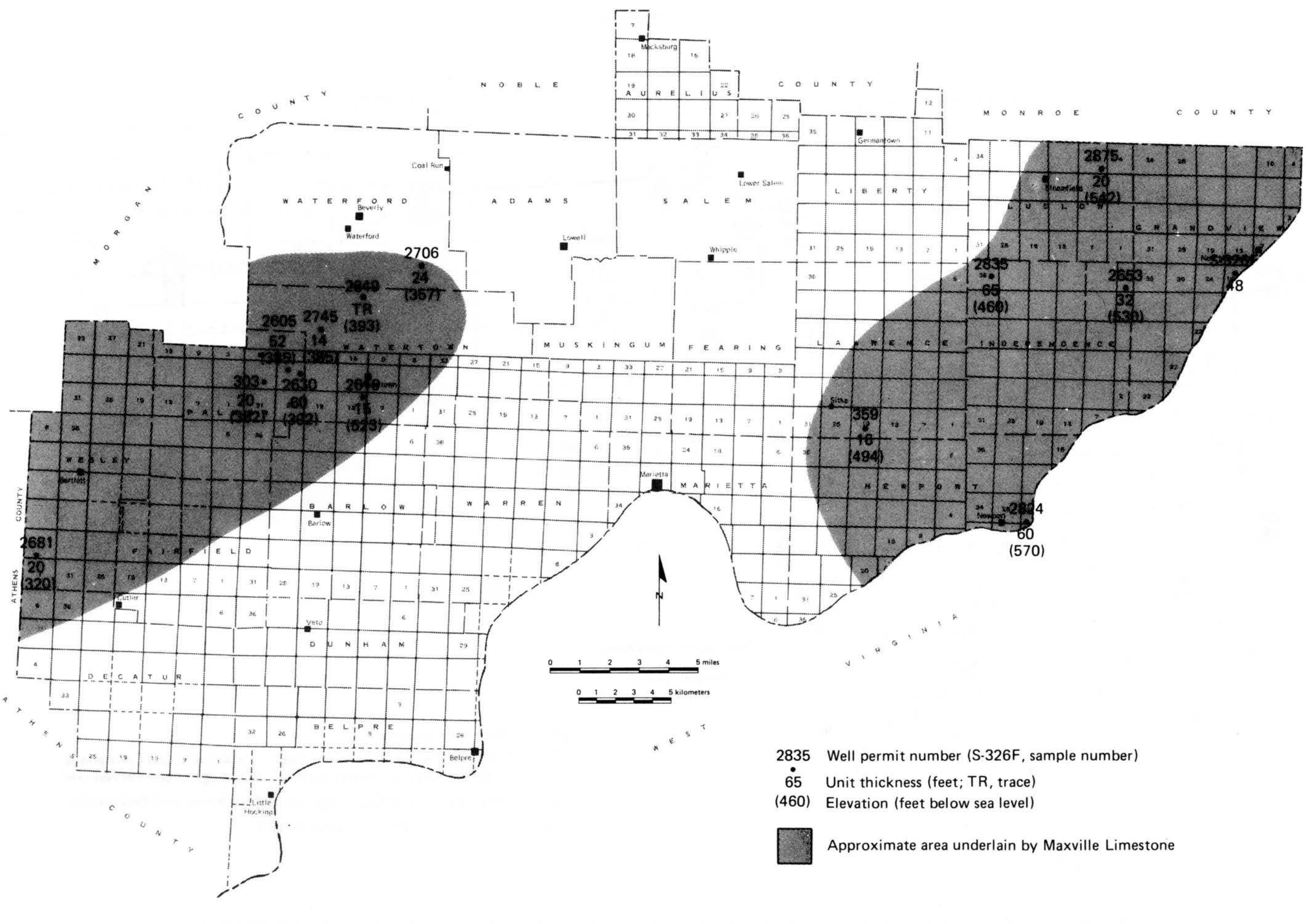


FIGURE 24.–Distribution and thickness of the Maxville Limestone in Washington County, Ohio.

Mississippian sands are in nearly every case much cleaner than the overlying Pottsville sands and tend to completely disaggregate when drilled, whereas the Pottsville sands are commonly well cemented and do not readily disaggregate.

Using the Berea Sandstone as a datum plane, relief of 185 feet can be demonstrated on the post-Mississippian–pre-Pennsylvanian surface in Washington County between the Cullen well (P-2835, SE¼ sec. 36), Independence Township, and the Gustke well (P-2582, NW¼ sec. 14), Warren Township (see A-A' and B-B', pl. 9A). Relief of this order is well within the absolute range of 350 to 400 feet suggested by Hyde (1953, p. 58). The two widely separated areas of Maxville Limestone (fig. 24) in eastern and western Washington County represent topographic highs on the post-Mississippian erosion surface.

## PENNSYLVANIAN SYSTEM

### GENERAL STATEMENT

The subsurface Pennsylvanian rocks of Washington County include the Pottsville and Allegheny Groups and the lower half of the Conemaugh Group. These groups on the crop consist of a cyclical sequence of sandstones, shales, limestones, siltstones, mudstones, clays, coals, and minor amounts of other rock types. As mentioned in the discussion of surface rocks these subdivisions were originally made on the basis of the number of mineable coals. Stout (1931) called attention to the fact that the limestones from the base of the system to the Strasburg coal (Pottsville to mid-Allegheny) are all of marine origin and that the limestones between the Strasburg coal and Skelley limestone (mid-Allegheny to mid-Conemaugh) are of both marine and freshwater origin. A third division with all freshwater limestones is present above the Skelley limestone.

The subsurface data for Washington County are sparse and in some instances of poor quality; however, the authors feel that except as noted the general character of these beds is essentially the same as elsewhere in Ohio.

Neither the Pottsville nor the Allegheny Group is exposed at the surface in Washington County, but some general data are available from well sample descriptions. Elsewhere in Ohio, on the outcrop, the Pottsville consists of a repetitive sequence of thick shales, sandstones, and conglomerates, thin coals and clays, and marine flints, limestones, and ironstones. Pottsville coals are generally too thin to be of commercial value but a few are of sufficient thickness to be mineable locally. The rocks of the Allegheny Group are quite similar to those of the underlying Pottsville except for a greater number of relatively thick and economi-

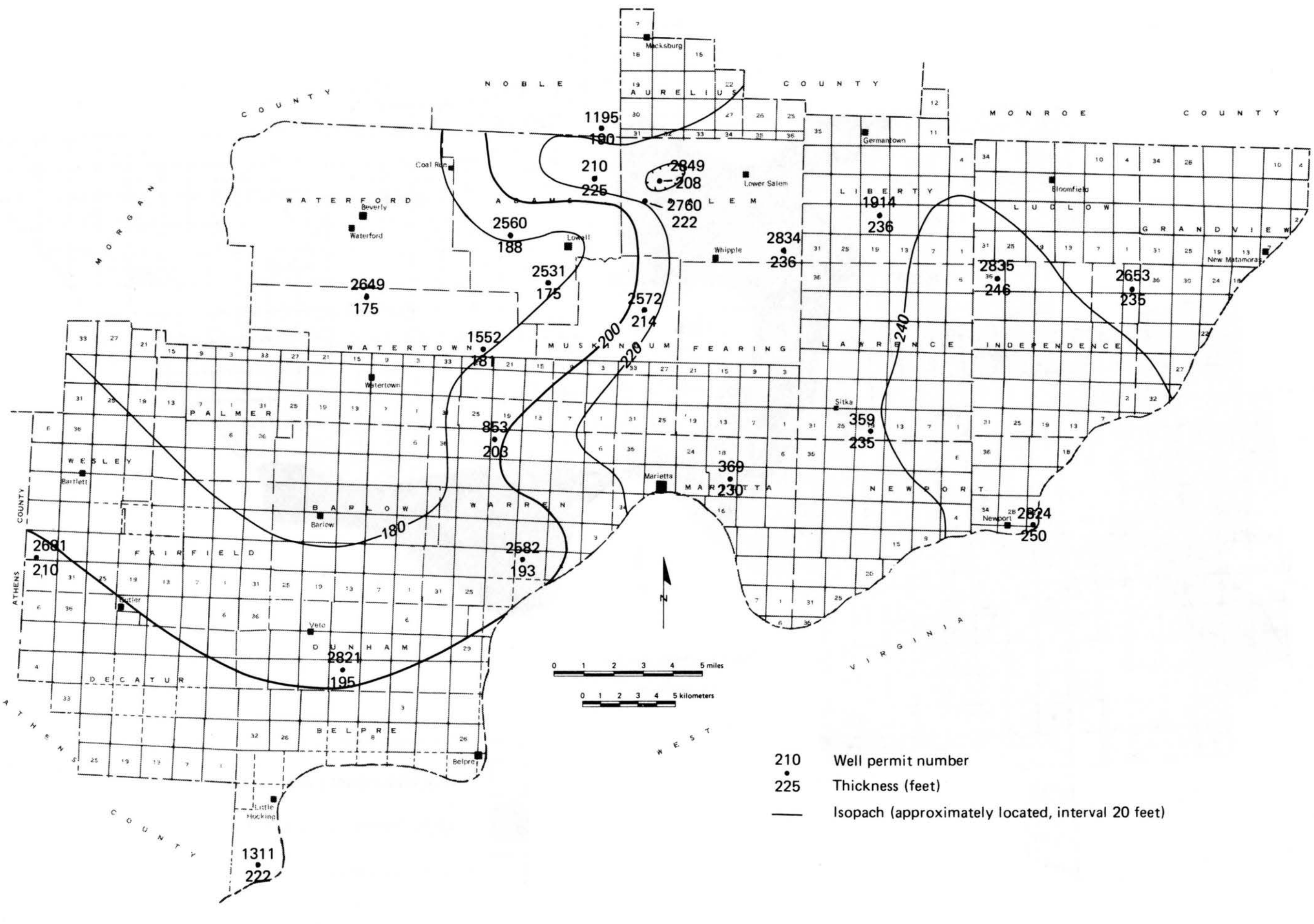


FIGURE 25.–Isopach map of the interval between the first appearance of red beds and the Ames limestone in Washington County, Ohio.

cally important coals in the Allegheny, along with nonmarine limestones. The boundary between the Pottsville and Allegheny Groups in the northern Appalachian Basin has traditionally been placed at the Brookville coal.

The authors were unable to distinguish the Pottsville from the Allegheny in this county on the basis of well samples. Marine zones found in a few samples (pl. 9A) may represent named outcrop units, but the sparsity of occurrence made attempts at correlation unwise. The rocks of these two groups seem to be essentially the same as those described on the outcrop, although generally the marine beds and the thick coals were not as readily recognizable on the basis of well cuttings. A coal tentatively identified as the Middle Kittanning was found rather consistently at about the same position in a number of wells in the north-central portion of the county. Bownocker and Dean (1929, p. 72) said "two test wells drilled in Salem Township, Washington County, showed 5 feet 8 inches and 4 feet 5½ inches" of the Middle Kittanning. However, the thick coal at one of these localities (core 192) may represent the Lower rather than the Middle Kittanning. Figure 35 shows the suggested area of occurrence for this coal. A fuller discussion of these data is given in the chapter on mineral resources.

The combined thickness of the Pottsville and Allegheny Groups, using the base of the red beds as the top of the Allegheny, ranges from about 400 feet along the Athens County line to approximately 600 feet along the Ohio River between Newport and Grandview Townships (pl. 9A). The thickness along the Athens County boundary compares favorably with that of the outcrop to the west in Athens and Vinton Counties. The increase to 600 feet along the eastern border of the county reflects the well-defined eastward-thickening trend of rocks in this area.

## DESCRIPTION OF UNITS

### Gray-red boundary

In outcrop the Upper Freeport coal marks the Allegheny-Conemaugh boundary; well cuttings from Washington County and adjacent areas were examined for evidence of this coal. Coal was found sporadically throughout the samples examined, but definite correlation could not be made with the outcrop or in most cases from well to well. There is, however, in the argillaceous units near the base of the Conemaugh, a marked change in color that serves to mark the boundary. The appearance of red mudstones and shales in the Conemaugh produces a marked contrast to the

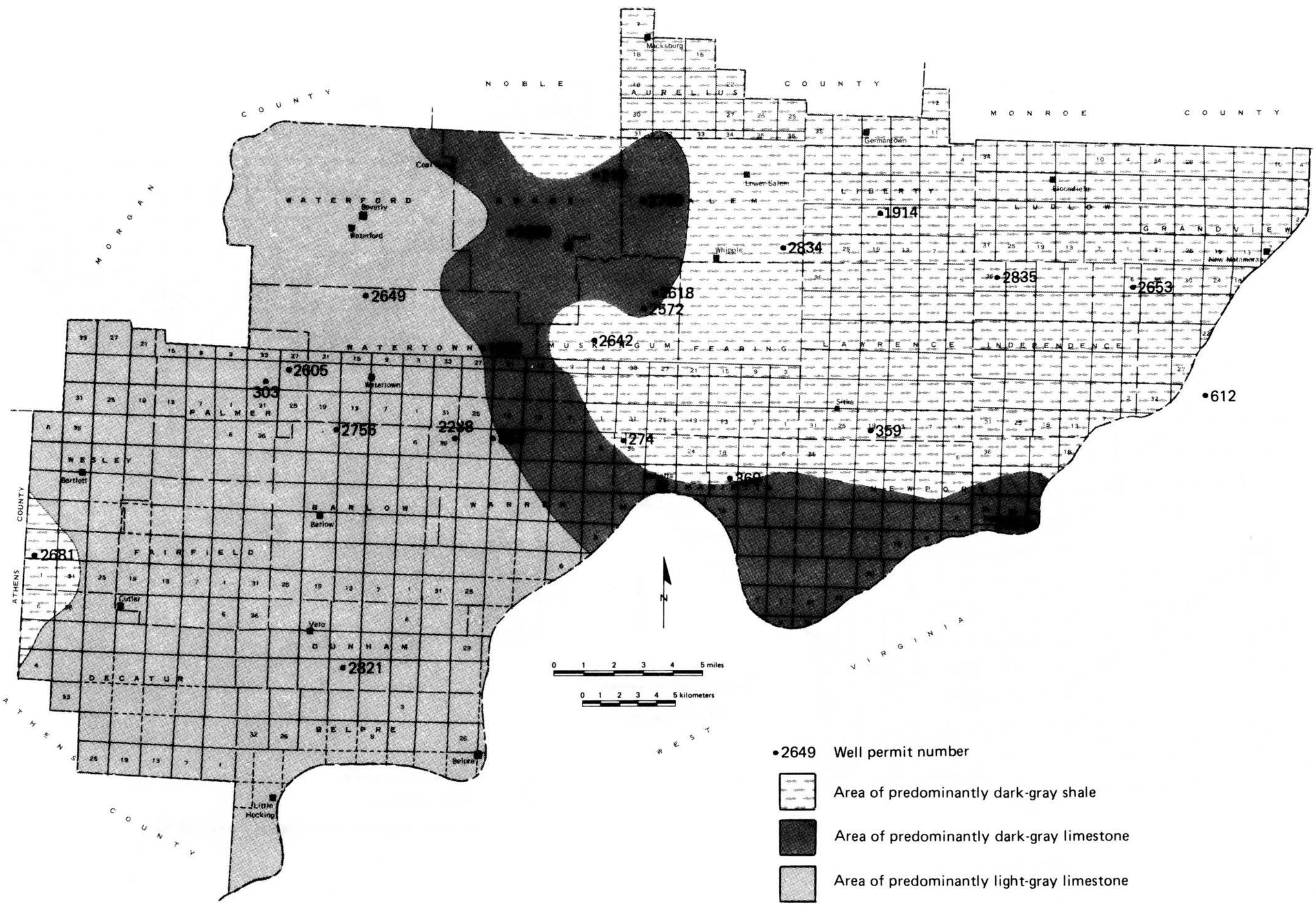


FIGURE 26.—Map showing the distribution, dominant lithology, and color of beds at the Brush Creek limestone position in Washington County, Ohio.

argillaceous gray units of the Allegheny.

Dark-red ironstone and pink to reddish limestones are found in both the Pottsville and Allegheny, but not with sufficient regularity or in sufficient abundance to produce the striking color noted in the argillaceous rocks of the Conemaugh.

The value of the first appearance of red beds as a group boundary was recognized long ago by White (1903, p. 226), who stated:

> Viewed from the standpoint of change in physical conditions the proper place for . . . a dividing plane between the Conemaugh and Allegheny beds, would be the first general appearance of RED ROCKS . . . about 100 feet under the Ames or Crinoidal limestone horizon.

The interval in Washington County from the bottom of the "reds" to the Ames limestone as shown by figure 25 is considerably greater than that noted by White for West Virginia. This difference is explained by the fact that White was speaking of an overall appearance of red beds rather than the first appearance:

> No RED BEDS whatever are found from the base of the Pottsville up to the top of the Allegheny, and none worth considering until after the epoch of the Upper Mahoning sandstone.

The work of the writers in Washington County and closely adjacent areas and that of Sturgeon (1958, p. 101) in Athens County indicates that red beds occur rather consistently below the lowest Conemaugh marine units (pl. 9A) and not far above the position of the Upper Freeport coal. A definite appearance of abundant red shales and mudstones was noted in about the same stratigraphic position in 94 percent of the samples examined.

The interval between the gray-red boundary and the Ames limestone (fig. 25) increases about 75 feet from west to east across the county. This thickening is in keeping with the general west-to-east trend noted for the county.

## Brush Creek limestone

The most persistent units in the Conemaugh are the marine beds in the lower half of the group. Of these, the Brush Creek limestone is the lowest recognized in Washington County. It ranges from a medium-dark- to dark-gray to black marine shale in the eastern half of the county to a dark- to light-gray marine limestone in the western half. A transitional belt of dark-gray limestone is found between these two areas. The distribution of these various lithologies and colors is shown in figure 26.

Throughout much of Ohio two Brush Creek marine

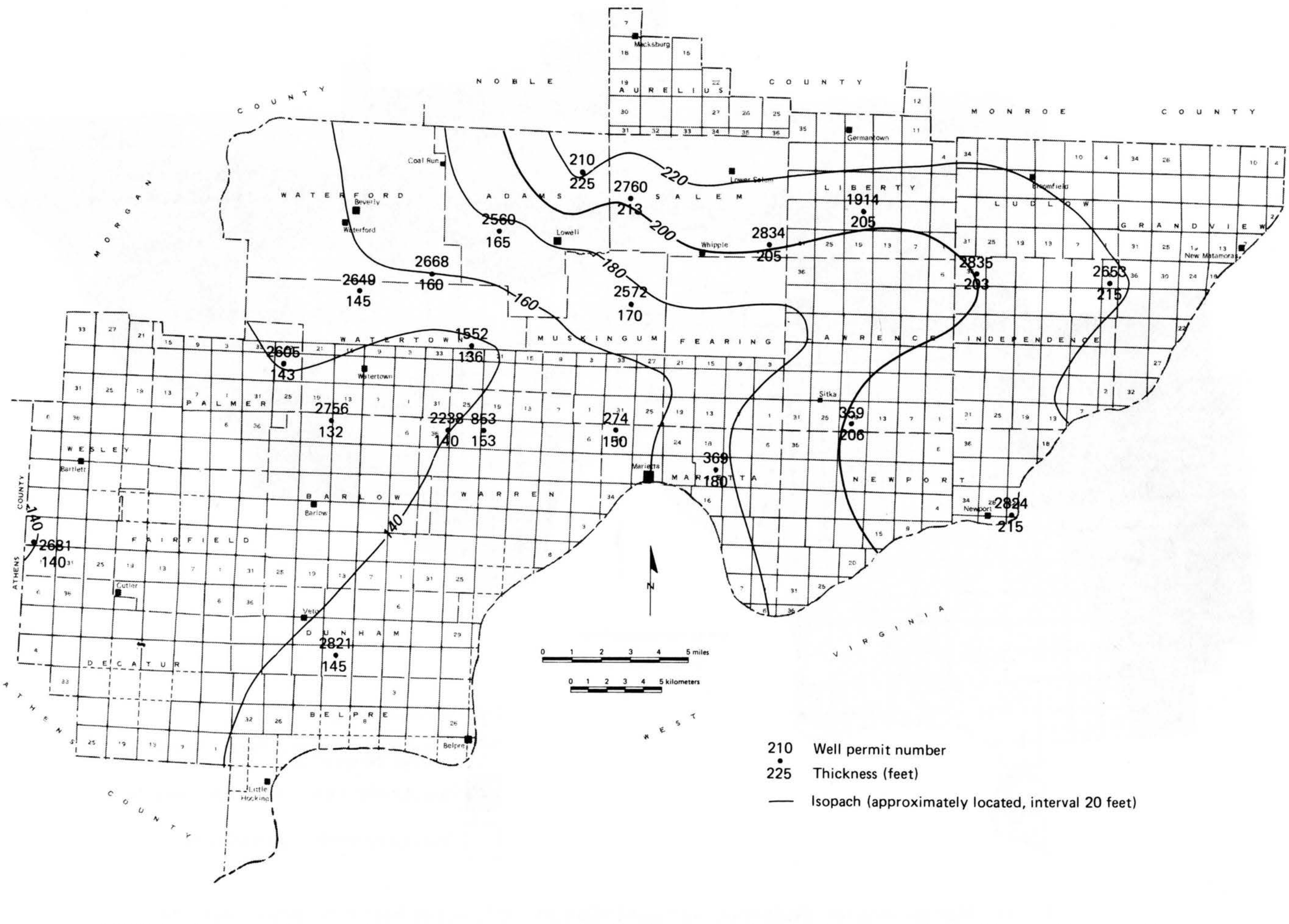


FIGURE 27.–Isopach map of the interval between the Brush Creek and Ames limestones in Washington County, Ohio.

beds have been recognized. Stout (1927, p. 358) stated:

> With few exceptions in eastern Ohio the [Brush Creek] consists of only one stratum of calcareous material but in central and southern Ohio it is normally made up of two beds of limestone or flint separated by from 10 to 30 feet of shale. This doùble structure is well recognized in Lawrence, Gallia, Vinton, Meigs, Athens, Perry, and Morgan Counties.

A marine zone which the authors have identified as Brush Creek (pl. 10) was present in 82 percent of the well samples examined; two marine zones were not distinguished at this stratigraphic position.

The Brush Creek has a variable thickness, but it is uniformly thicker than any of the higher Conemaugh marine beds and may be 25 to 30 feet thick in the eastern portion of the county. It is possible that the thicker zones represent the two beds seen on the outcrop, but cannot be clearly identified as separate units because they are separated only by a thin nonfossiliferous layer not obvious in the well samples.

The interval between the Brush Creek and Ames limestones increases from 140 feet in the west to about 220 feet in the east (fig. 27), reflecting the general eastward-thickening trend across the county.

### Cambridge and Portersville limestones

Examination of samples from 33 wells that penetrated the strata between the Brush Creek and Ames limestones revealed a marine unit in the position of the Cambridge limestone in 49 percent of the samples and in the position of the Portersville in 61 percent. Marine units were noted at both positions in only 20 percent of the wells.

The limited data available do not warrant the construction of isopach maps using either of these units as end members. In general it may be said that one or more marine units are found between the Brush Creek and the Ames limestones; where two units are present, they are commonly separated by an interval of 10 to 25 feet. These units are found 50 to 105 feet and 85 to 140 feet, respectively, below the Ames limestone.

### Ames limestone

The Ames limestone is the single most persistent of the Conemaugh marine beds. It was found in 91 percent of the wells described, although it is normally only 1 to 2 feet thick and can be easily overlooked in the samples. It may be as much as 15 feet thick in a few places. The Ames is most

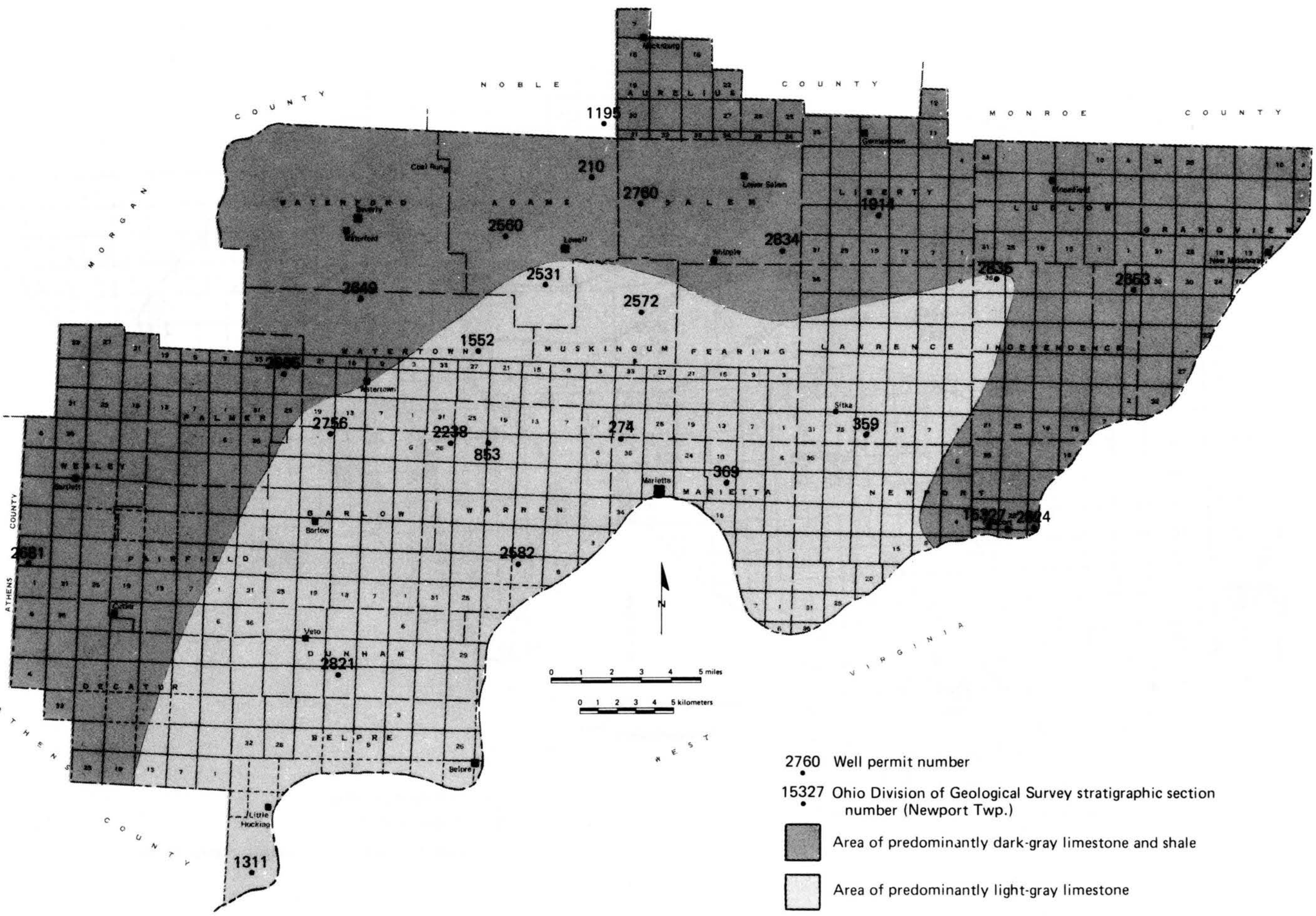


FIGURE 28.–Map showing the distribution, dominant lithology, and color of beds at the Ames limestone position in Washington County, Ohio.

commonly a slightly glauconitic light- to dark-gray limestone, although at a few localities fossiliferous shale is the predominant lithology. A trend toward light-gray limestone was noted in the south-central and southwestern portions of the county. Figure 28 indicates the areas of predominance of light-gray limestone and of darker limestone and shale.

Although thin, the Ames limestone is a good marker bed and is useful in subsurface stratigraphic work. The intervals from the Ames to the Pittsburgh and Meigs Creek coals are useful tools in anticipating the depth at which the Ames might be expected (see pl. 9A). The Ames-Pittsburgh interval in Washington County ranges from 220 feet in Salem Township to 288 feet in Liberty Township. The Ames-Meigs Creek interval ranges from 314 feet to 390 feet in the same townships. The Pittsburgh and Meigs Creek are generally not found southwest of the Muskingum River; in that area, the Washington coal is relatively persistent and normally is found an average of 670 feet above the Ames limestone.

The Ames is present above drainage only in a very small area of secs. 3, 4, and 33E, Newport Township, where the unit is brought to the surface along the crest of the Newell Run anticline immediately adjacent to the Ohio River. The rapid dip to both east and west from along the crest and the northward plunge of the anticlinal axis carry the unit below drainage within a distance of 1 mile. It may best be seen in sec. 33E in the highway cut facing the river, where stratigraphic section O.G.S. 15327 (p. 13) was measured.

### Skelley and Gaysport limestones

Limestones or, in places, shales bearing marine fossils were found from 15 to 55 feet above the Ames Limestone in wells in Adams Township (P-2531, P-2560), Lawrence Township (P-359), Liberty Township (P-1914), Salem Township (P-2760), and Watertown Township (P-2649) (table 2) and in outcrop in Newport Township (O.G.S. 15327, p. 13). The unit described in the single outcrop section is tentatively identified as the Skelley limestone. Marine zones were found in one set of well samples (P-2760) at both 20 and 35 feet above the Ames. The Gaysport and Skelley limestones have been identified rather widely in outcrop in eastern Ohio at 15 feet and 35 to 40 feet, respectively, above the Ames. Plate 9 shows the relationship of these marine zones to the Ames limestone in Washington County.

The few data available to the writers are not sufficient to definitely correlate these zones with either the Gaysport or Skelley limestone. The problem of correlation of these units has been alluded to by Sturgeon (1958, p. 142), who stated:

> Several points should be remembered in considering the correlation of marine members above the Ames limestone in eastern Ohio:
>
> 1. That Gaysport has been identified as Skelley, and vice versa,
> 2. That the Gaysport may be only a split from the Ames,
> 3. That locally in Athens County the Ames limestone is definitely two limestone benches separated by several feet of fossiliferous marine shale.

It is probable that above the Ames there is a marine complex which at the present time is very imperfectly understood.

# Chapter 4

## STRUCTURE

### GENERAL STATEMENT

The first reference to structure in Washington County seems to have been made by Andrews (1861):

I have recently traced a most interesting line of uplift and dislocation from the eastern part of Washington County, Ohio, to beyond the great oil wells on the Little Kanawha River. The direction of it is nearly north and south. It makes an angle of about 40° with the general course of the Allegheny Mountains. As seen in Ohio it presents a well marked anticlinal axis but with the eastern slope more steep than the western.

This "line of uplift" referred to by Andrews is the Burning Springs anticline of West Virginia and its northward extension into Ohio. Minshall (1888, p. 466), discussing the Macksburg oil field, spoke of

three well marked anticlinals, which may be designated the Liberty, the Lawrence and the Newport arches.

These features were identified by Minshall through a series of level lines run specifically to find structures in the area.

Structure maps were made for the Meigs Creek (No. 9) coal (pl. 1) because it is the most important coal in the county in terms of economic potential and for the Washington coal and the Berea Sandstone (pls. 10, 11) because these units represent the highest and lowest beds for which sufficient data points were available for detailed structural mapping. A 50-foot contour interval was used for the Meigs Creek coal and a 100-foot interval for the Washington coal and Berea Sandstone.

The principal structural trends on these three units show excellent agreement; minor structural dissimilarities between the units can be readily explained either by lack of data for some beds or by. the relatively better definition given some features by the 50-foot contour interval used on the Meigs Creek coal. The geologic history of the area suggests that the principal structural features should be present, though perhaps diminished, at least to the depth of the Silurian salt beds.

There are six structural features of sufficient magnitude to be worthy of mention: the Newell Run anticline, the Cow Run anticline, the Liberty arch, the Cambridge arch, the Parkersburg syncline, and the Parkersburg-Lorain syncline. The first three of these features are considered parts of the Burning Springs anticline, but the individual names are retained. These six features have two major directional trends, which dominate the structural framework of the county. The Parkersburg-Lorain syncline and the Cambridge arch trend northwest-southeast, and the Parkersburg syncline and the Burning Springs anticline system trend north-south (fig. 29). There has been a suggestion by W. H. Smith (1948, p. 236) that the Cow Run uplift may have an east-west axial trend. Although the axis is slightly arcuate, the gross directional trend of the structure was found to be north-south (pls. 1, 10, 11). No east-west trend of any magnitude was found, although some minor features do deviate from the dominant directional trend.

### DESCRIPTION OF FEATURES

#### BURNING SPRINGS ANTICLINE

The Burning Springs anticline of West Virginia has been described by Wilson (1951) as consisting of three *en echelon* elongate domes which he called the Burning Springs, Volcano, and Horseneck domes, respectively, from south to north. The axis of the structure is somewhat sinuous, with each individual dome offset slightly from the adjacent dome. Wilson's mapping of Horseneck dome immediately adjacent to the Ohio border was used (pl. 10) by the authors with slight modification to show the relationship of the Ohio portion of the Burning Springs anticline to the main structure in West Virginia.

The axis of the Burning Springs anticline crosses the Ohio River into Washington County slightly downstream from the village of Newport and extends by way of a sinuous series of greatly diminished flexures (pls. 1, 10, 11) to the vicinity of the common boundary between Washington, Noble, and Monroe Counties. There is some suggestion that the structure continues north along the Noble-Monroe County line; however, an investigation of this area was beyond the scope of the immediate study.

Rodgers (1963) has postulated that the Burning Springs anticline was formed by imbricate thrusting of strata immediately overlying Silurian salt. The salt (Salina $F_4$ salt of Clifford, 1973), which terminates along the trend of the anticline, acted as a glide plane for a large block of strata being shifted to the northwest; increased frictional resistance along the westward pinch-out of the salt resulted in thrust faulting and formation of the structure. Gwinn (1964, p. 868) cited unpublished dipmeter surveys that show undeformed strata below the salt zone; however, there are insufficient data in the Washington County area to make detailed structure maps on units below the salt. Assuming the salt did serve as a glide plane, the good correlation between the major structural elements on units in the interval from the Berea Sandstone to the Washington coal would imply that these features should continue to at least the depth of the salt.

#### NEWELL RUN ANTICLINE

The Newell Run anticline is not a distinct and separate structural unit but rather the northern extension of the Horseneck dome of West Virginia into Newport Township, Ohio, and is the most pronounced anticlinal structure in Washington County. Closure measured on the Berea Sandstone is on the order of 260 feet. Taken from the Washington coal, total closure on the Horseneck dome is approximately 500 feet. The familiarity of this anticline to Ohio geologists and its somewhat unusual features warrant individual attention and retention of the name Newell Run.

The axis of Horseneck dome has a north-south trend to within about 1 mile south of the Ohio River, where it swings sharply to the northeast (pl. 11), roughly parallels the river for about 2 miles, and hooks abruptly to the northwest near the village of Belmont, West Virginia, before crossing the Ohio River. The structure plunges to the northwest, and the surface expression disappears in a short distance along Newell Run.

The sharp swing of the axis in the vicinity of the Ohio River is suggestive of transverse faulting, with the long northeast reach of the river flowing along a possible fault zone. A northeast-southwest transverse fault system is also indicated by the offset farther south between the Horseneck and Volcano domes.

## COW RUN ANTICLINE

The Cow Run anticline is a small structure centered on Cow Run in southern Lawrence Township. This feature, another of the *en echelon* domelike structures which comprise the Burning Springs anticline system, is greatly diminished in magnitude relative to the main portion of the Burning Springs structure to the south. The axis is sharply offset to the west from the axis of the Newell Run extension of the Horseneck dome, suggesting possible transverse faulting between the two structures. The Cow Run axis is only slightly offset to the west from the main axis of Horseneck dome (pl. 10). A fault showing a displacement on the Meigs Creek coal of about 192 feet is postulated on the northwest flank of the structure (pl. 1).

## LIBERTY ARCH

Minshall (1888, p. 466) mentioned the presence of an arch in Liberty Township; the arch was revealed by a level line run through the area. A low nose having a slight northeasterly trend is shown on the Washington coal structure map (pl. 10) as roughly centered in the township. This feature has better definition on the Meigs Creek structure map (pl. 1) because of the smaller contour interval; closure is on the order of 60 feet.

The Liberty arch is north of and generally in line with the Cow Run anticline and Horseneck dome to the south, although greatly diminished in magnitude; this arch is another in the series of highs related to the Burning Springs


FIGURE 29.—Approximate locations of the principal structural axes in Washington County, Ohio.

anticline.

The Liberty arch is not clearly defined by structure contours drawn on the Berea Sandstone (pl. 11); however, this weakness in definition is believed to be a result of lack of data in this area. The broad terrace shown on the Berea map suggests a possible structural high in this locality.

## CAMBRIDGE ARCH

The Cambridge arch is a rather weak element in the structural framework of the county and is shown only by the gentle nosing of the Washington and Meigs Creek coals and the Berea Sandstone in Aurelius and Salem Townships. This is the southern extremity of the Cambridge arch, which plunges gently and dies out to the southeast. All three structure maps indicate that the Cambridge arch does not extend across the county and is not a northern extension of the north-south-trending Burning Springs anticline.[1] The axis of the Cambridge arch has a definite northwest-southeast orientation and essentially parallels the axis of the Parkersburg-Lorain syncline.

## PARKERSBURG-LORAIN SYNCLINE

The most prominent structural feature in the area is the very broad northwest-southeast-trending syncline occupying most of the western half of the county. Stout and others (1935, p. 898) described the structure in the following terms:

> The most outstanding structural feature of the eastern half of the state is the Parkersburg syncline, a deep trough which can be traced on surface beds from Parkersburg on the Ohio River, northwest to Lorain County at Lake Erie.

Structure contours drawn on the Washington coal (pl. 10) show the long axis of this structure to extend from just east of Parkersburg, West Virginia, northwestward through Beverly in Waterford Township and into Center Township, Morgan County. The trough is quite wide in the southern half of the county and, on an east-west line through Marietta, extends from western Newport Township to Wesley Township. Contours drawn on the Berea Sandstone (pl. 11) indicate that the long axis is located several miles east of Parkersburg and goes approximately through Moore Junction and Beverly.

A strong trough on the east flank of the Parkersburg-Lorain syncline (pls. 11, 12) essentially parallels the axis of the Burning Springs anticline system and compares favorably with the trend of the Parkersburg syncline as shown by Cardwell and others (1968) on the geologic map of West Virginia.

It appears that there has been no clear distinction made between the Parkersburg syncline (of West Virginia usage), which parallels the Burning Springs anticline, and the Parkersburg-Lorain syncline (of Ohio geologists), which is reported to parallel the Cambridge arch. That two such distinct synclinal trends, with a bifurcation several miles east of Parkersburg, are present is rather clearly shown on both the Berea and Washington structure maps. A restudy of the structural elements of this portion of the state and the immediately adjacent area of West Virginia is in order. For the present, however, the term Parkersburg-Lorain syncline is retained for the northwest-trending trough, and the name Parkersburg syncline is used for the north-trending depression paralleling the Burning Springs anticline.

## OTHER STRUCTURAL FEATURES

### MINOR FOLDS

The Berea, Meigs Creek, and Washington structure maps all show many minor lows, noses, and highs. Most of these features are too small or indefinite to warrant individual names and many of them are interpreted as diagenetic or depositional rather than tectonic in origin. Some of them undoubtedly contribute to the localization of oil and gas.

### STREAM PATTERNS

The number of straight stream segments having right-angle or near-right-angle changes in direction, particularly in the eastern half of the county, is amazingly large (pl. 1). In many areas stream patterns of this type are related to faulting or to joints, although the authors were unable in Washington County to make a definite correlation with either factor.

Bearing directions were determined for all straight stream segments over 1,000 feet in length and of sufficient width to be shown by a double blue line on a 7½-minute quadrangle. There are at least 244 such straight stream sections and 83 essentially right-angle changes in stream direction. Figure 30 indicates the major directional groupings and percent of straight stream segments in each bearing group for the 244 measurements.

Right-angle or near-right-angle changes in stream direction on Duck Creek and the Little Muskingum River (pl. 1) are particularly numerous. The lower Muskingum River and the Ohio River also show numerous straight reaches and sharp changes in channel direction. These stream features are particularly noticeable along the trend of the Burning Springs anticline. Stream patterns in adjacent areas of West Virginia have similar patterns.

Direct evidence of faulting, such as vertical displacement or actual fault planes, was not observed; however, there are a number of factors which could partially explain this fact. In Washington County the surface stratigraphy along the axis of the Burning Springs anticline consists of a repetitive sequence of shales, sandstones, siltstones, mudstones, limestones, and thin coals. There are no true "key" beds and rapid lateral changes in stratigraphy are the norm; thus meaningful correlations must be based on comparing a relatively large number of long, measured stratigraphic sections. Partial sections in many cases cannot be correlated over even relatively short distances. The difficulties of correlations are compounded further by a lack of good exposures.

The problem of adequate correlations would allow displacements of small magnitude to escape detection easily. The exposed stratigraphic sequence is composed largely of

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[1] Clifford and Collins (1974), on the basis of work done after the present manuscript was prepared, reported "The [Cambridge] arch follows the pinchout of the Salina E salt; east of the pinchout, elevations of the Pittsburgh coal (Pennsylvanian) are about 300 feet higher than in the west. There is only a gentle southeastward dip below the salt. The structure is interpreted to be the result of movement of a southeastward-thickening block of supra-Salina rocks northwestward along a salt glide plane. A postulated near vertical tear fault (or series of faults) marks the western limit of this movement."

incompetent beds, and fault planes could not be recognized easily even if good exposures were not severely limited. Strike faults with little vertical displacement would be even more difficult to recognize.

Data on the Berea Sandstone adjacent to several straight stream segments suggest minor displacements at these localities, but these data are either too sparse or of questionable reliability and hence are of little value in positive identification of possible fault zones.

If the relatively large number of right-angle stream patterns are related to faults rather than to some other factor such as joints, vertical displacements must be relatively small, and an extremely detailed study must be made before an accurate analysis of the problem will be available.

## JOINTS

Stream patterns are related to jointing in many in-

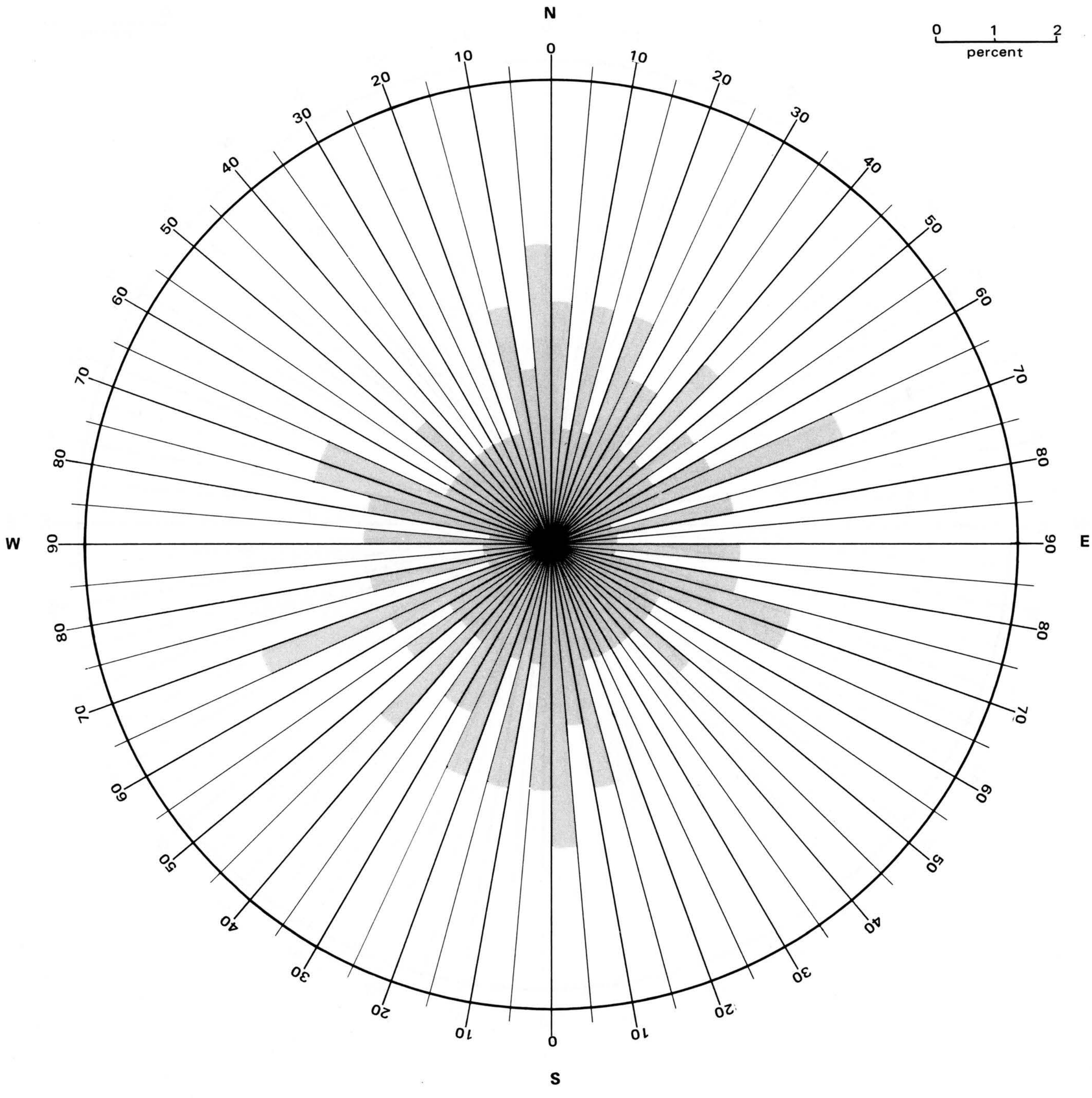



FIGURE 30.—Rose diagram showing strike directions of 244 straight stream segments in Washington County, Ohio.

stances, and for this reason 242 joint measurements were made in Independence, Lawrence, Liberty, Ludlow, Marietta, and Newport Townships. Four readings, on the average, were taken at each of approximately 60 locations. These data, while not statistically rigorous, do provide some insight on the structural aspect of the area. A composite rose diagram of the strikes of these joints shows five principal joint sets (fig. 31), four of which form two essentially right-angle joint systems. These five include sets striking between (1) N. 80° W. and N. 90° W., (2) N. 65° W. and N. 75° W., (3) N. 55° W. and N. 60° W., (4) N. 15° E. and N. 25° E., and (5) N. 35° E. and N. 40° E. Sets numbered 2 and 4 and numbered 3 and 5 form essentially right-angle joint systems.

A rose diagram showing the directional bearings of straight stream segments was made for the Little Muskingum

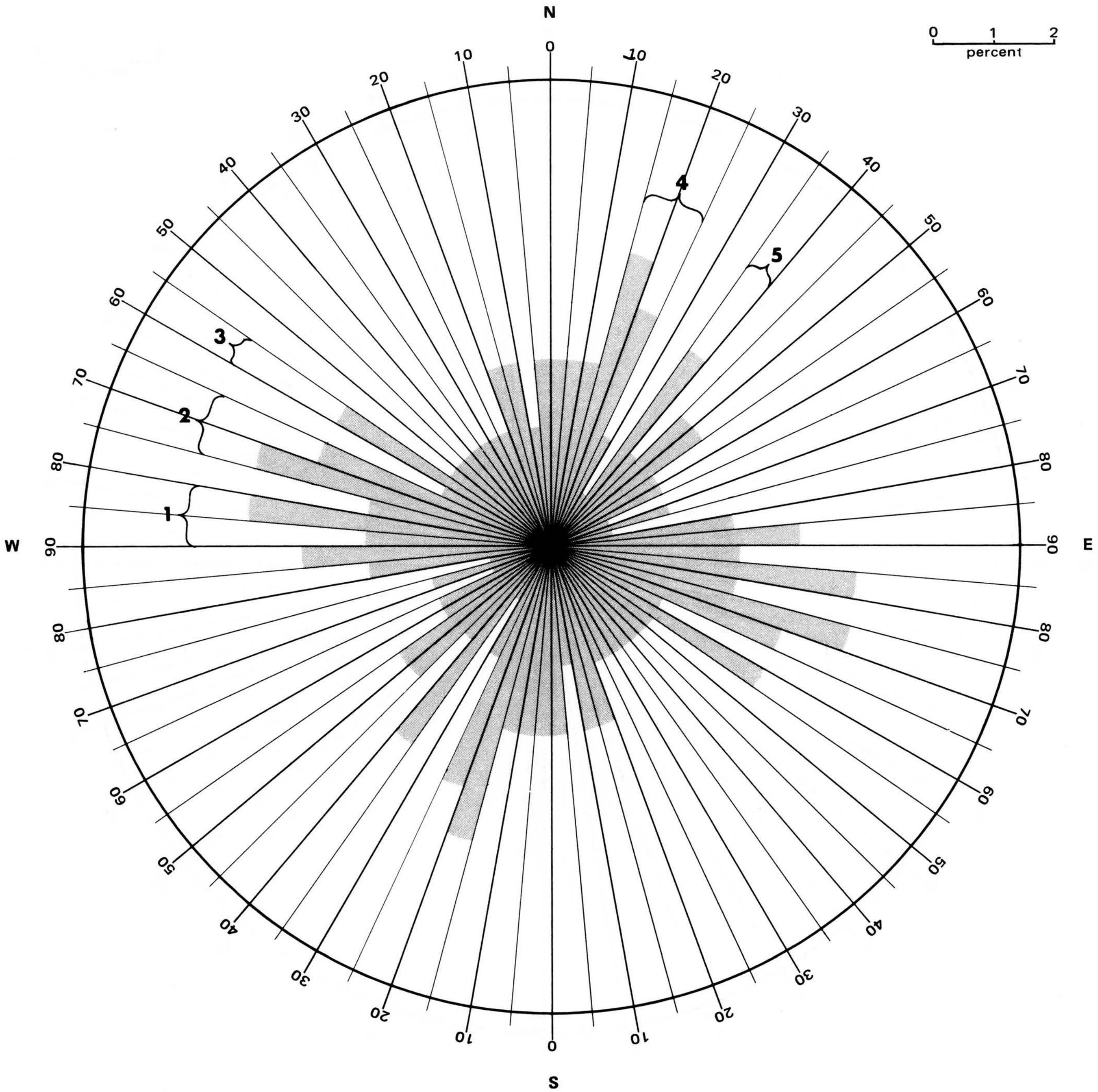



FIGURE 31.–Rose diagram showing strikes of 242 joint measurements from Independence, Lawrence, Liberty, Ludlow, Marietta, and Newport Townships, Washington County, Ohio.

River (fig. 32), which drains most of the area in which joint measurements were made. A comparison of the strikes of the straight stream segments with those of the principal joint sets (fig. 33) shows that, although there are similarities in the two patterns, there are also significant differences. The large number of segments striking in the general directions of joint sets 1, 2, 3, and 4 suggests a relationship between these stream segments and the joint systems. However, the lack of correlation with joint set 5 and the relatively large number of stream segments not in close alignment with any major joint system suggest that other factors may be influencing the stream pattern.

A larger statistical sampling of both joint and straight stream segment directions in adjacent counties of Ohio and West Virginia should provide additional valuable data on this aspect of the regional structure.

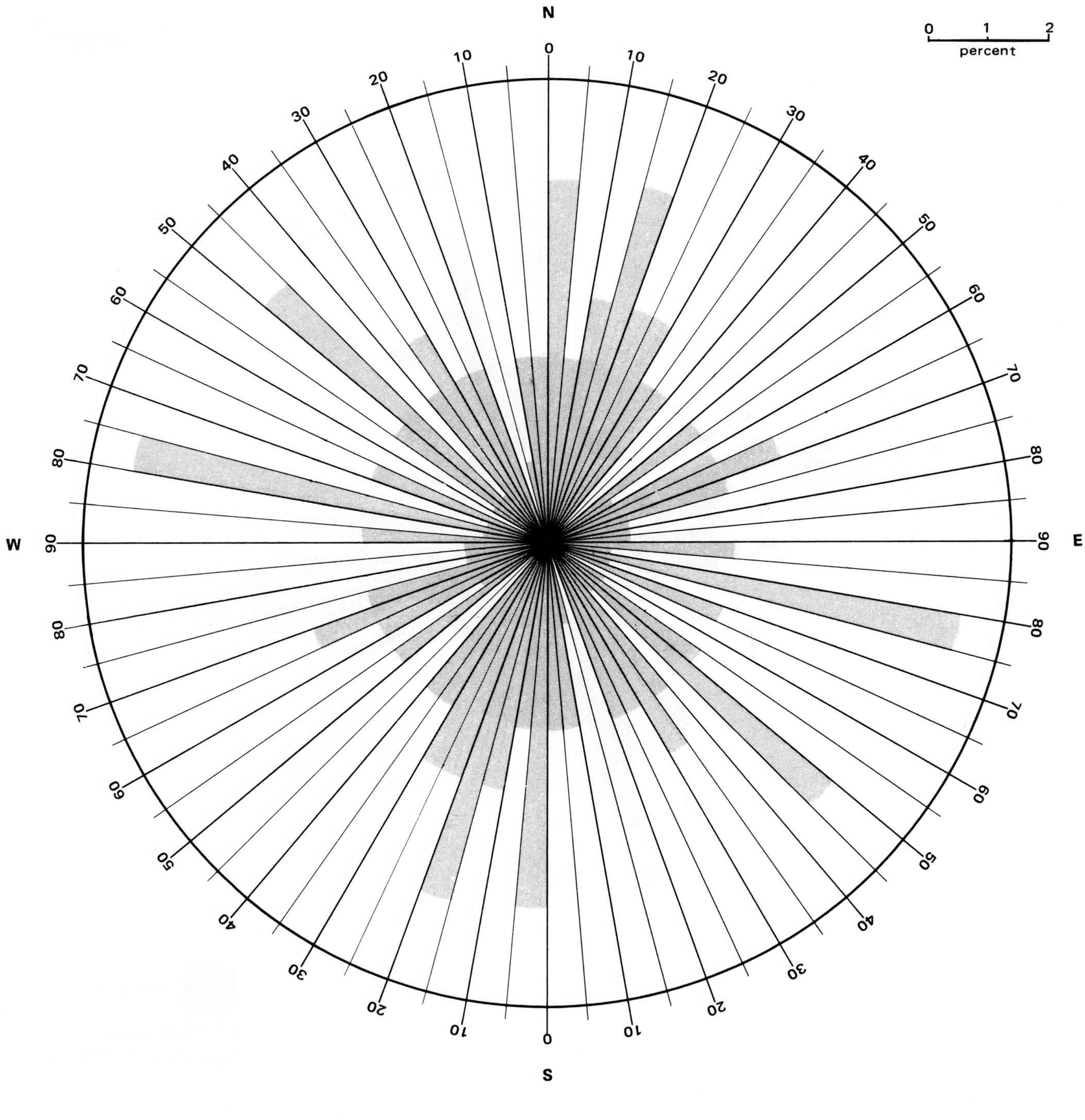



FIGURE 32.—Rose diagram showing strike directions of straight stream segments for the Little Muskingum River in Washington County, Ohio.

## FAULTS

No faults of a substantial magnitude were observed directly in the county. Each of the principal highs of the Burning Springs anticline is offset from the adjacent segment on the south. This offsetting is suggestive of northeast-southwest transverse faulting. The lack of readily apparent vertical displacement coupled with a suggested northeast-southwest trend would indicate strike-slip faulting.

In sec. 20, Lawrence Township, the elevation of the Meigs Creek coal (pl. 1), changes about 192 feet in a horizontal distance of approximately half a mile, indicating possible faulting. At this locality, on the northwest flank of the Cow Run anticline, the Meigs Creek coal on the southeast has moved up relative to the regional dip. This movement could be the result of a small high-angle reverse

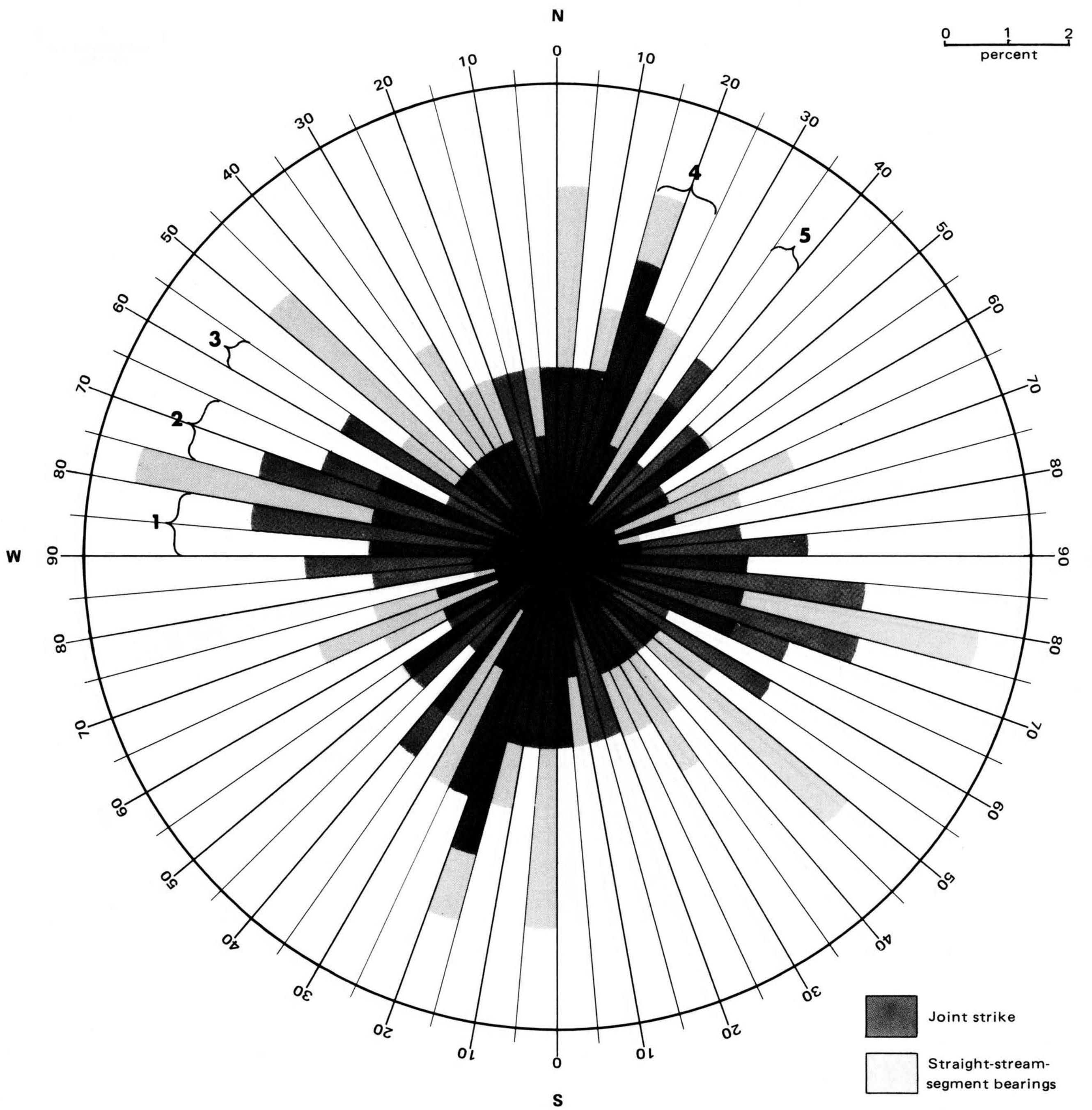



FIGURE 33.–Composite rose diagram showing joint strikes and bearings for straight stream segments for the Little Muskingum River in Washington County, Ohio.

fault striking northeast-southwest and downthrown on the northwest. The possibility that this feature could be attributed to a sharp flexure rather than to faulting cannot be overlooked, however. Steeply dipping limbs changing rapidly to beds with low dips and yet remaining unbroken have been reported by Wilson (1951) and seen by the senior author on the Burning Springs structure to the south. Confidential seismic data indicated a fault, at depth, parallel to and about half a mile northwest of the fault drawn on the Meigs Creek coal. In this instance the downthrown block is on the southeast. Lockett (1947, p. 437) also cited confidential information in support of the statement:

> Extensive northeast-southwest faults, with the downthrow on the southeast, have been identified by seismic work in southeastern Ohio.

# Chapter 5

## ENGINEERING GEOLOGY

Geologic conditions which favor landslides and general foundation instability create untold problems for property owners and for highway and construction engineers. The terms landslide, soil creep, and rock fall are used here in a general sense for the more common types of mass-wasting found in Washington County. Readers interested in details and in more precise definitions of these phenomena are referred to Sharpe (1938) and Savage (1951).

Because of the geologic environment and heterogeneous nature of the rocks of Washington County, special consideration should be given to selection of construction sites. Each rock type has distinct engineering, hydrological, and geological characteristics which should be considered both individually and in combination. Specific factors affecting stability in Washington County as well as in much of eastern Ohio are (1) presence of a number of relatively incompetent rock units, (2) steep slopes, and (3) excessive moisture. In this region the principal rock types with inherent incompetency are mudstones and clays. These units lack internal cement, are only weakly cohesive, have internal slippage planes, and in many places contain expanding clays. Excessive moisture lubricates the individual clay particles and internal slip planes, reducing the already low cohesive strength. If expandable clays are present, they will swell and increase the plastic property of the unit. Excess moisture also adds substantial weight to a potential slide mass and increases pore-water pressure, which in turn lowers the cohesiveness of the mass. These factors are at work continuously in nature and are greatly accelerated by activities of man, who may add greater surface loads than the unit can bear or may create instability through excavations or may remove natural support areas. Natural failures can be seen throughout the county in the many hummocky hillsides, tilted trees, and canted fence lines. The fact that most mudstones are unstable in nature should be adequate warning that extreme caution is required in activities involving construction on such units unless engineering design is adequate to insure site stability.

Surficial materials such as sand and gravel give little trouble from an engineering standpoint; however, Wisconsinan lake clays found in terrace remnants in the major tributaries to the Ohio and Muskingum Rivers could be troublesome. Pre-Illinoian lake deposits (pl. 1) in the western half of the county also contain some clay. Lake clays are extremely unstable when wet, and caution should be exerted if building sites are to be located on these materials. Webb and Collins (1967) discuss a landslide occurring as a result of road construction in thick lake clays (Minford Silt).

Bedded shales are much more competent than mudstones or clays, but less so than sandstones or limestones. Earlier geologic workers in eastern Ohio did not always distinguish between bedded shales and the very incompetent nonbedded mudstones or "red beds" of the region. This is an important distinction to be made. The interested reader is referred to the discussion of rock types on page 11.

Sandstones, siltstones, and bedded limestones are relatively competent and do not generally create stability problems; however, there are individual characteristics associated with each type which should be considered in combination with such other factors as jointing, water-carrying capacity, relationship to other rock units of greater or lesser competency, and relationship to slope. Coal is a very brittle rock and should not be used as a bearing surface.

Jointing can be an important factor in rock falls. Such falls, which generally take place with great speed, occur most commonly in situations where road or other construction has resulted in a vertical or near-vertical cliff composed of both competent and incompetent units. Sheer bluffs of thick jointed sandstone underlain by mudstone like those along Ohio Rte. 7 just south of Marietta are classic situations for rock falls. Two large rock falls have in fact occurred on this stretch of Rte. 7 (Engineering Experiment Station, 1950, p. 1); one of these falls, at least, was of sufficient magnitude to completely block the highway. Joints were cited as a cause, and undoubtedly did play a role in these falls. Joints are fracture areas which may carry considerable amounts of water, provide sites for freeze-thaw activity, and provide planes along which major blocks can become detached from the bed. Where underlain by incompetent mudstones the weaker unit erodes more rapidly than the sandstone, creating a load imbalance which ultimately results in movement of the joint-bounded block. A heavy rain which thoroughly saturates the rock units and lubricates existing planes of slippage generally triggers the actual fall.

Thick sandstone units which commonly have joint spacing on the order of tens of feet yield very large rock falls when conditions favoring falls are created. Thin-bedded limestones, on the other hand, generally have joint spacing on the order of several inches to a few feet. Instead of yielding major falls, such rock units, given comparable conditions, produce a steady "rain" of smaller blocks which, while much less likely to cause major damage, can provide a constant maintenance and clean-up problem.

The closeness of the joint spacing can also be a factor in the water-carrying capacity of a unit. Coals are generally very intensely jointed on very close spacing; it is this jointing and not inherent permeability and porosity which makes coals good water carriers.

The water-carrying capacity of a rock unit is important in that water is the lubricating agent in landslides and in soil creep. Rocks with high porosity and permeability are capable of carrying even larger amounts of water in cases where permeability has been increased by jointing. Spring lines and features such as natural topographic benches or shoulders in some places mark the position of a coal or sandstone. Units such as mudstones, shales, and clays, which have low permeability, do not allow the passage of water through the body of the rock unit. If incompetent units are associated with units with high water-bearing capacity, potentially unstable conditions can be created (fig. 34).

The major rock falls on Rte. 7 south of Marietta exemplify what can happen when construction creates an unnatural situation involving an incompetent unit overlain by a unit of much greater competence. In this case highway construction created greatly oversteepened slopes which overloaded the incompetent beds. As previously mentioned, the failure was aided by the jointing and the water-bearing capacity of the sandstone. To avoid creating similar situations, care must be exercised in selection and design of construction sites.

Slope is another major factor in landslides. Movement of a flat surface is practically ruled out, even where the area is underlain by relatively incompetent rocks. However, very steep or vertical cliffs are obviously prime sites for rock falls even if the rocks are very competent. Relative steepness of a slope will affect also speed of movement; landslides may range from rapid falls and massive amounts of material to very slow but steady downhill creep of the soil mantle. A proper combination of rock type and angle of slope is therefore of prime importance in selecting construction sites.

Prevention of slides or management of active or potential slide areas may involve both passive and active modes. Zoning ordinances or land-use plans that prevent use of potential slip areas would be a passive mode, prohibiting construction activities where slides are a potential problem, or, if building is required, demanding that certain precautions (active mode) be followed to establish maximum stability of the site.

Active measures are those which seek to stabilize already unstable areas or to prevent movement where construction must take place. Such measures would have as first priority the control of water. As stated previously, water acts as a lubricant, allows clayey rocks to become

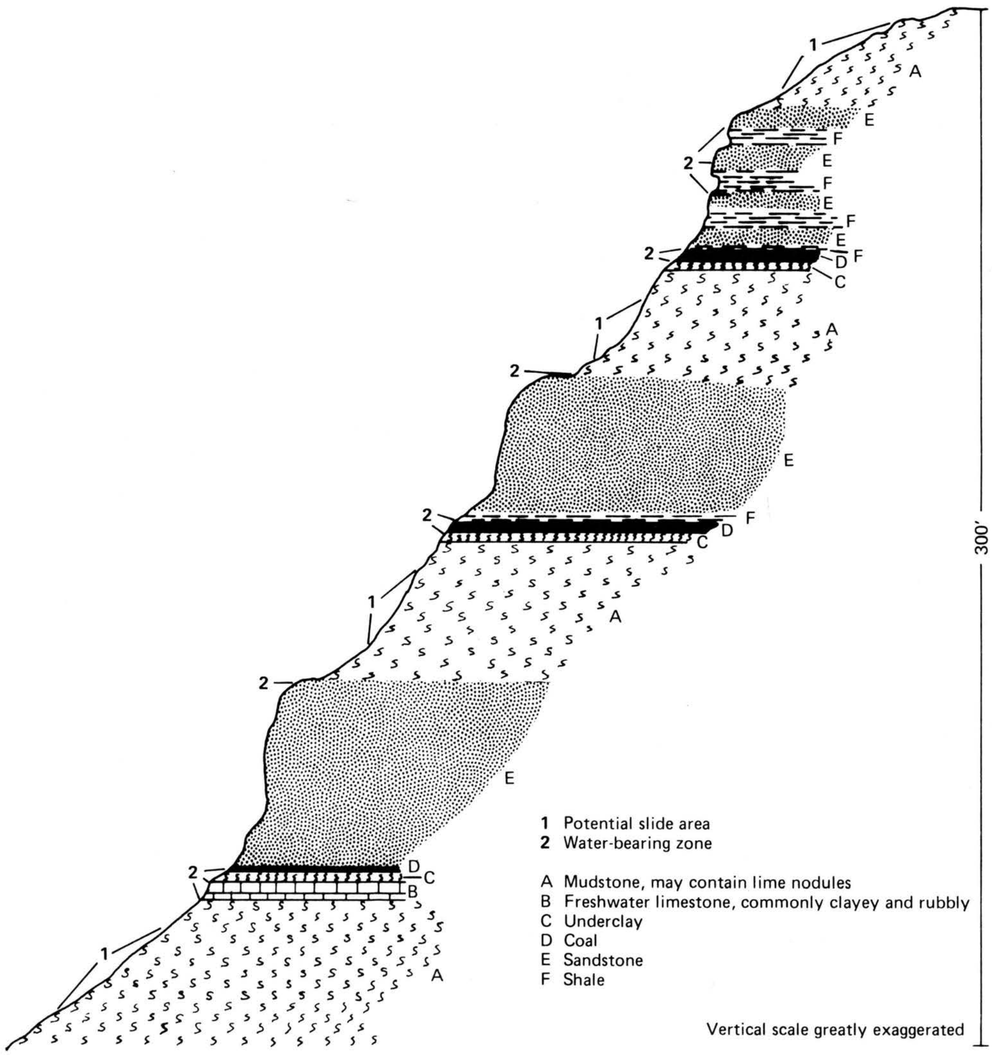



FIGURE 34.–Generalized column in the Marietta area illustrating incompetent (unstable) beds and competent (stable) units on the same hillside.

plastic, increases the weight of potential slide material, and increases pore-water pressure within the material. All of these are significant factors in sliding. Diversion of water away from unstable sites and removal of water within the site of tiling, blind drains, and ditches contribute to stabilization of the ground. Other active efforts would include careful pre-evaluation by an experienced geologist, driving of piling or building cribs, and proper design of slopes based on an evaluation of rock type. In many cases the benching of slopes is sufficient to catch falls or slides and thus prevent damage to structures below.

The nature of the geology of Washington County is such that it is difficult to give more than these general guidelines. Thickness and lateral continuity of individual beds are very different from place to place, and sites must be evaluated individually. For insights into conditions throughout the county the interested reader is directed to the geologic map and to those sections of this report which discuss the general geology, the individual beds, and the detailed stratigraphic sections.

# Chapter 6

## MINERAL RESOURCES

### INTRODUCTION

The mineral resources of Washington County have been exploited since the earliest white settlers appeared in the area. Although not at present a state leader in mineral production, the county has good potential for an expanded mineral industry. The following discussion treats mineral resources that are currently exploited or have been exploited in the past and those which seem to have future development potential.

### COAL

Coal is reported to have been mined from the bed of the Muskingum River at Coal Run as early as 1826 (Hildreth, p. 320). This early observation notes that during low-water stages coal was pried from the river bed with crowbars. Coal was probably known to the early settlers before this time; however, no mention of it was made by the usually alert Hildreth in an 1819 letter describing the region. The first official coal tonnage reports appeared in 1867. In that year 2,000 tons of coal were reported to have been mined in the county (Ohio Geological Survey, 1956). Even though coal was mined from 1867 to the present, no appreciable amount of coal was produced until 1948[1], when 190,587 tons were mined. Washington County's greatest production year was 1957, when 250,055 tons were reported to have been mined. In 1968 the reported tonnage was 106,586.[2] The grand total of coal reported mined in the county for the period 1867 to 1967 is only 3,076,126 tons.

#### RESOURCES AND CLASSIFICATION

Resources of the Pittsburgh (No. 8) and Meigs Creek (No. 9) coals in Washington County have been computed by DeLong (1955) and by W. H. Smith and others (1952), respectively. Denton (1960) has made resource tabulations for the Uniontown (No. 10), Waynesburg (No. 11), Waynesburg "A", and Washington (No. 12) coals. The methods used to calculate resource tonnages for the above coals are discussed by each author. In general it may be stated that, because of the nature of the coals and the quality of the information available to DeLong and to W. H. Smith and others, an evaluation procedure that was much more comprehensive and rigorous than that used by Denton was applicable. A discussion of the various techniques used in Ohio in coal resource work and of the relative merits and circumstances leading to the use of each method is given by Brant and DeLong (1960, p. 12-17). The Uniontown, Waynesburg "A", and Washington coals occur in small isolated patches of sufficient thickness (14 inches) to qualify technically as resources. These three coals in Washington County are very irregular in both thickness and distribution, and resources cannot be calculated by the methods normally used. Denton used statistical methods to compute resource tonnages for these coals in Washington County as well as in other parts of the state. In the authors' opinion, for irregular coals such as these, the data available were not sufficient for the method used by Denton. Resource tonnages are in most cases probably much less than previously reported. The potential of these coals as a fuel supply is not sufficient to warrant a detailed study of their resources, but for each of these seams the authors have indicated their opinion on the amounts of coal potentially available.

In Ohio, coal resource computations have not been made for coals less than 14 inches thick.

#### DESCRIPTION OF UNITS

##### COALS OF THE ALLEGHENY GROUP

Middle Kittanning (No. 6) coal was reported by Bownocker and Dean (1929, p. 72) to be present in two tests drilled in Salem,Township. Thicknesses of 5 feet 8 inches and 4 feet 5½ inches of coal were given for these two sites. A record (O.G.S. core 192) of a hole drilled in the southeast corner "Fraction Lot No. 55," Salem Township, shows about 4 feet 6 inches of coal near the middle of the Allegheny Group. The coal identified in this log as Middle Kittanning was found 595 and 686 feet, respectively, below the Pittsburgh and Meigs Creek coals. Middle Kittanning coal is believed to be present in this area, but it is the authors' opinion that the thick coal reported by Bownocker and Dean in core 192 may be the Lower Kittanning (No. 5) coal. This log undoubtedly represents one of the tests cited by Bownocker and Dean (p. 72); unfortunately the exact location of the test is uncertain. There are two lots numbered 55 in this township; one lot is located in the Duck Creek Allotment about half a mile north of the village of Bonn and the other is in the U.S. Reverted Lands approximately 2 miles west of Warner. A thickness of 2 feet for the Pittsburgh coal is reported in the same core; this leads the authors to believe that the locality just north of Bonn is the probable site of this hole. West of Lower Salem the Pittsburgh seam thins in a short distance to less than 14 inches, and stratigraphic evidence indicates that this coal facies disappears not too far west of Warner. The logs of the other test were not available, and no evaluation of that information was possible.

[1] Unless otherwise indicated all production data in this report are from the annual reports of the Ohio Division of Mines.

[2] Production figures for subsequent years are: 1969, 117,274 tons; 1970, 35,423 tons; 1971, 227,569 tons; 1972, 205,734 tons; no production was reported for 1973 and 1974.

The possibility that pods of mineable coal may be present at moderate depths in the north-central portion of the county cannot be overlooked; it is entirely possible that both the Middle and Lower Kittanning coals are of mineable thickness. This possibility warrants serious consideration by those companies searching for additional fuel reserves. Although the use of oil and gas well samples and records for locating potential coal resources is less than satisfactory, data from these sources may be used as a general guide in the absence of more reliable information. Sample cuttings were described from wells drilled in Salem and adjacent townships; coals which would seem to correlate with the Upper Freeport (No. 7), Lower Freeport (No. 6A), Middle Kittanning, Lower Kittanning, and Clarion (No. 4A) were found at several localities. However, these identifications must be regarded as highly speculative and subject to revision if additional data become available. Correlation between coals in sample suites of individual wells was in most cases not sufficiently good to warrant extrapolation of thickness or areal extent. It is believed that this is largely a matter of sample quality. However, in each well shown on figure 35, coal accounted for 10 percent or more of the sample at a depth of about 300 feet below the Ames limestone. Coal in this position is 2 feet thick in core 192 and would most probably correlate with the Upper or Lower Freeport coal. Correlation of the Allegheny coals as well as of other units will require much work on a regional scale. Further core drilling will be required to determine the extent and character of any potentially mineable deep coal in this general area of the county.[3]

## PITTSBURGH (NO. 8) COAL

The Pittsburgh coal occurs in mineable thickness in Washington County in two widely separated small areas (fig. 5). The extent of thick Pittsburgh coal in western Washington County is unknown, but Peters (1947) reported that the Arcadia Coal Company bought coal rights in the Federal Creek field in secs. 4, 5, and 33 of Decatur Township. The thickest coal is found in the southern portion of the field in south-central sec. 4, where 96 inches of coal is reported by Peters (p. 141). A shaft 120 feet deep was sunk to this seam by the Arcadia Coal Company in 1892, but the extent of mining at this locality is unknown. On the basis of data from Peters and from physical evidence in the vicinity of the mine shaft, the amount of coal removed is believed to have been quite small.

G. E. Smith (1952) apparently did not have access to the data given in Peters' history; consequently his figures of coal thickness for the southern end of the Federal Creek field are, in part, in error.

The Pittsburgh coal in the Federal Creek field is rather uniformly divided into two benches separated by a white to light-gray clay parting. This parting, known as the "White Elephant" to the local inhabitants, is reported to be 1 foot thick at the Arcadia shaft. There are no chemical analyses of this coal from western Washington County, but a sample taken 1½ miles west of the county line at Broadwell, Athens County, had the following analysis (as-received basis): moisture, 6.6 percent; volatile matter, 35.05 percent; fixed carbon, 48.15 percent; ash, 10.2 percent; sulfur, 3.41 percent; B.T.U., 11,893.

A single coal thickness figure is not sufficient to make an estimate of resources for an area. However, the Pittsburgh was reached by shaft and slope in Big Run valley about half a mile west of the Athens-Washington County line, and it is felt that there is a strong possibility that a substantial field of coal lies athwart this line within a mile of the Baltimore and Ohio Railroad at Beebe, Athens County.

A second area of Pittsburgh coal is located in the north-central and eastern portions of the county, where marginally mineable coal is found in portions of Aurelius, Fearing, Lawrence, Liberty, Ludlow, and Salem Townships (fig. 5).

Outside the Decatur Township area, the thickest Pittsburgh coal is found in Salem Township in the vicinity of the town of Lower Salem. The coal at this site has been the subject of considerable geologic controversy and a brief discussion of this dispute will be found in the chapter on stratigraphy.

The greatest portion of the coal in the Lower Salem field is in the 14- to 28-inch thickness category; however, there are a few highly localized areas of coal up to 36 inches thick. The average coal thickness, based on 19 measurements, is only 25 inches. The Pittsburgh in this region is generally impure and ranges from bright and blocky to bony, shaly, or canneloid. In places the unit is more of a coaly shale than a true coal. The following partial stratigraphic section, measured about 3.2 miles northeast of Lower Salem, Salem Township, illustrates the nature of this seam:

O.G.S. 8823, Salem Twp., SE¼ of the NE¼ of the NE¼ sec. 25, Dalzell 7½- and Macksburg 15-minute quadrangles. Measured in stream bed, along road, and on eroded slope. Measured by G. Bell. Base elevation 740 feet (barometer).

| | ft | in | ft | in |
|---|---|---|---|---|
| *Units 15 through 63 omitted* | | | | |
| *Coal identified in original section as Lower Salem* | | | | |
| 14. Coal, bony to shaly | 0 | 1 | 10 | 7 |
| 13. Clay shale, brown | 0 | 2 | 10 | 6 |
| 12. Coal, blocky to shaly | 2 | 3 | 10 | 4 |
| *Units 1 through 11 omitted* | | | | |

The Pittsburgh coal in both Lawrence and Ludlow Townships is generally thinner than in the Lower Salem field and is located along the valley of the Little Muskingum River, where the coal is at the surface along the eastern edge of the Liberty arch (fig. 29). On the basis of five observations in each township, coal of resource thickness is an average of 17 inches thick in Lawrence Township and 19 inches thick in Ludlow Township.

The Pittsburgh has been sampled at three localities in the county for chemical analysis:

O.G.S. 6837, Ludlow Twp., NE¼ sec. 27, Rinard Mills 7½- and New Matamoras 15-minute quadrangles. Measured along Sackett Run.

[3] Subsequent to preparation of this discussion two studies have been made which essentially verify the correlations and the suppositions that mineable coals are probably present at depth in the north-central portion of the county. Struble, Collins, and Kohout (1971) and Struble, Collins, and DeLong (1976) report 49 inches of Middle Kittanning coal in sec. 28, Liberty Township (O.G.S. core 2386) and 42 inches of Bedford coal, 93 inches of Lower Kittanning coal, and 44 inches of Middle Kittanning coal in lot 3, Duck Creek Allotment, Salem Township (O.G.S. core 2181). Coals of mineable thickness were found also in immediately adjacent areas of Monroe and Noble Counties.

From these data it is strongly inferred that all or portions of Adams, Aurelius, Liberty, and Salem Townships are underlain by significant previously unknown coal resources.

Measured by A. T. Cross and D. A. Buck. O.G.S. chemical analysis 502.

| | ft | in | ft | in |
|---|---|---|---|---|
| *Units above coal omitted* | | | | |
| Coal, PITTSBURGH (No. 8), base elevation 675 feet | | | | |
| Shale, coaly; sampled | 0 | ½ | 4 | ½ |
| Coal, shaly; sampled | 0 | 2 | 4 | 0 |
| Coal, bony; sampled | 0 | 1 | 3 | 10 |
| Coal, bright, hard; sampled | 0 | 6½ | 3 | 9 |
| Coal, bright, hard; sampled | 0 | 7½ | 3 | 2½ |
| Coal, dull, attrital; sampled | 0 | 4 | 2 | 7 |
| Coal, bony; sampled | 0 | 1 | 2 | 3 |
| Shale, coaly, silty, thin-bedded; sampled for oil distillation (see 502-2, table 3) | 1 | 4 | 2 | 2 |
| *Units below coal omitted* | | | | |

O.G.S. 8246, Ludlow Twp., NW¼ sec. 33, Rinard Mills 7½- and New Matamoras 15-minute quadrangles. Measured along Wingett Run. Measured by A. T. Cross, W. H. Smith, and D. A. Buck. O.G.S. chemical analysis 503.

| | ft | in | ft | in |
|---|---|---|---|---|
| *Units above coal omitted* | | | | |
| Coal, PITTSBURGH (No. 8), base elevation 715 feet | | | | |
| Coal, shaly; sampled | 0 | 1 | 10 | 4 |
| Coal, blocky, somewhat bony, dull; sampled | 0 | 3½ | 10 | 3 |
| Coal, blocky; sampled | 0 | 3 | 9 | 11½ |
| Coal, bony, hard; sampled | 0 | ¼ | 9 | 8½ |
| Coal, blocky, hard; thin clay shale parting in middle; sampled | 0 | 9½ | 9 | 8¼ |
| Shale, coaly; sampled | 0 | ¼ | 8 | 10¾ |
| Coal, blocky, hard; sampled | 0 | 4½ | 8 | 10½ |
| *Units below coal omitted* | | | | |

O.G.S. 12539, Salem Twp., NE¼ sec. 35, Lower Salem 7½- and Macksburg 15-minute quadrangles. Measured in the J. O. Nesselroad mine. Measured by A. W. Seabright and I. Vaughn. O.G.S. chemical analysis 494, by D. J. Demorest.

| | ft | in | ft | in |
|---|---|---|---|---|
| Coal, PITTSBURGH (No. 8) | | | | |
| Coal, bony; rejected | 0 | 4 | 2 | 8 |
| Coal, calcite on faces; sampled | 0 | 4 | 2 | 4 |
| Coal, with pyrite streaks; sampled | 0 | 1 | 2 | 0 |
| Coal, some calcite; sampled | 0 | 7³⁄₈ | 1 | 11 |
| Coal, bony; sampled | 0 | ⅛ | 1 | 3⁵⁄₈ |
| Coal, sampled | 1 | 3½ | 1 | 3½ |

The analyses of these samples and the results of distillation tests by Krumin and others (1951) are reproduced in tables 3 and 4, respectively.

Mining of the Pittsburgh coal in the eastern part of the county has been restricted largely to "farm banks" for private and local use. There have been no active mines reported in this coal for several years. Andrews (1874) stated that in the days of coal oil distilleries a small

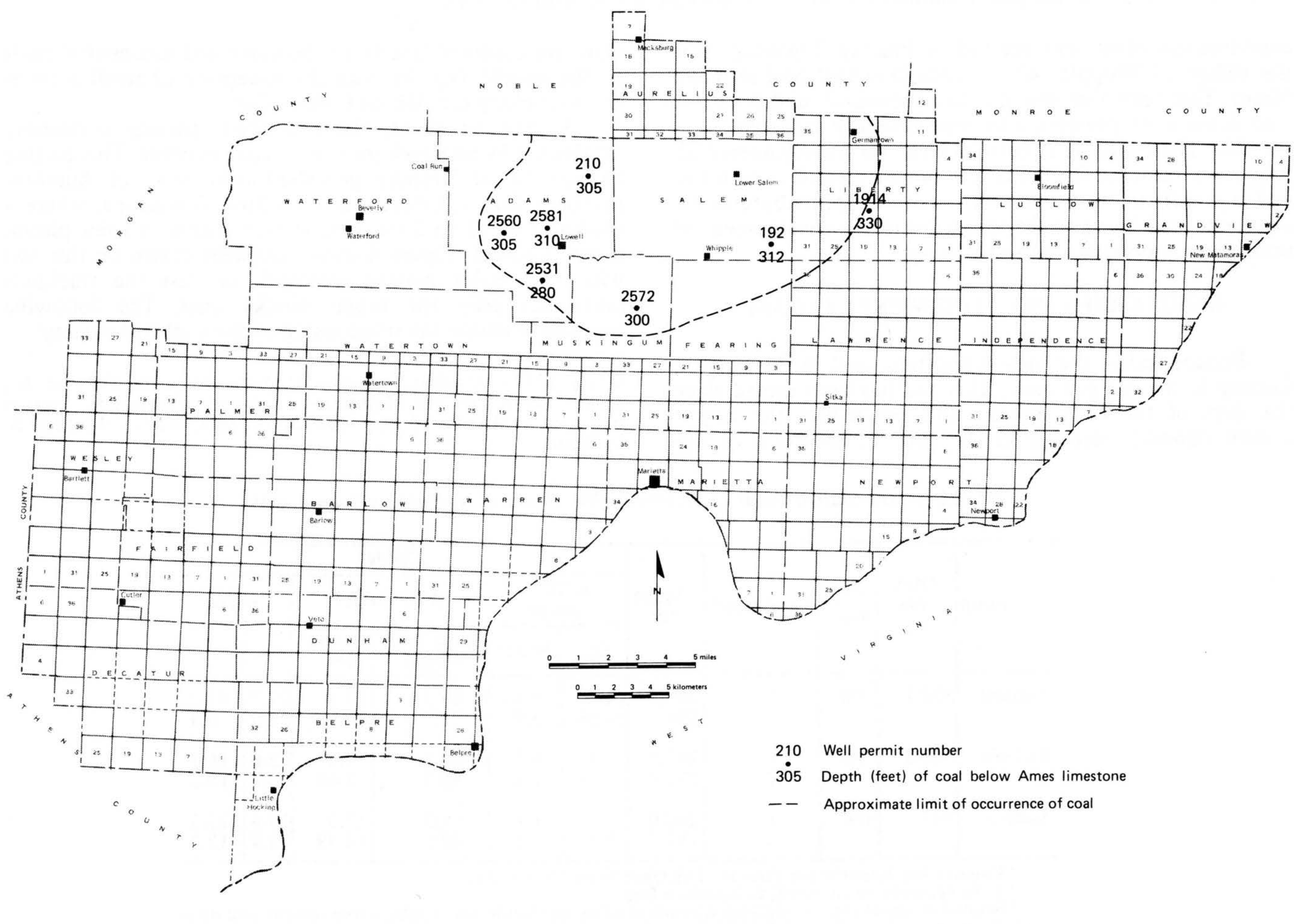



FIGURE 35.—Area of occurrence of coal of mineable thickness approximately 300 feet below the Ames limestone, Washington County, Ohio.

TABLE 3.—*Analyses of Pittsburgh (No. 8) coal in Washington County, Ohio*

| Township | OGS file no. | Kind[1] | Source[2] | Condition[3] | Proximate analysis | | | | Ultimate analysis | | | | | Heat value | | Ash fusion temperature (°F) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Moisture | Volatile matter | Fixed carbon | Ash | Sulfur | Hydrogen | Carbon | Nitrogen | Oxygen | Calories | Btu | Initial deformation | Softening | Fusion |
| Ludlow | 502 | 2 | 1 | 1 | 2.2 | 38.1 | 45.9 | 13.8 | 5.7 | 4.9 | 66.2 | 1.0 | 8.4 | 6744 | 12,140 | 2,030 | 2,080 | 2,330 |
| | | | | 2 | | 38.9 | 47.0 | 14.1 | 5.8 | 4.7 | 67.7 | 1.0 | 6.7 | 6894 | 12,410 | | | |
| | | | | 3 | | 45.3 | 54.7 | | 6.8 | 5.5 | 78.8 | 1.2 | 7.7 | 8028 | 14,450 | | | |
| | | | | 4 | | 43.5 | 56.5 | | | | | | | 8253 | 14,856 | | | |
| | | | | 5 | 2.7 | 42.3 | 55.0 | | | | | | | 8036 | 14,464 | | | |
| | 503 | 2 | 1 | 1 | 10.0 | 31.5 | 44.5 | 14.0 | 1.9 | 4.9 | 57.7 | 1.0 | 20.5 | 5472 | 9,850 | 2,090 | 2,170 | 2,350 |
| | | | | 2 | | 35.0 | 49.4 | 15.6 | 2.1 | 4.2 | 64.1 | 1.1 | 12.9 | 6078 | 10,940 | | | |
| | | | | 3 | | 41.5 | 58.5 | | 2.5 | 5.0 | 75.9 | 1.3 | 15.3 | 7201 | 12,950 | | | |
| | | | | 4 | | 40.1 | 59.9 | | | | | | | 7341 | 13,214 | | | |
| | | | | 5 | 11.9 | 35.3 | 52.8 | | | | | | | 6464 | 11,636 | | | |
| Salem | 494 | 1 | 2 | 1 | 2.19 | 41.06 | 46.00 | 10.75 | 5.19 | 4.91 | 68.37 | 0.70 | 10.08 | 6972 | 12,550 | 2,420 | | 2,507 |
| | | | | 2 | | 41.98 | 47.03 | 10.99 | 5.30 | 4.77 | 69.91 | 0.71 | 8.32 | 7128 | 12,831 | | | |
| | | | | 3 | | 47.16 | 52.84 | | 5.95 | 5.36 | 78.54 | 0.80 | 9.35 | 8008 | 14,415 | | | |
| | | | | 4 | | 45.74 | 54.26 | | | | | | | 8192 | 14,746 | | | |
| | | | | 5 | 2.56 | 44.57 | 52.87 | | | | | | | 7983 | 14,369 | | | |

[1] 1, Channel (mine); 2, channel (outcrop).
[2] 1, U.S. Bureau of Mines and/or U.S. Geological Survey; 2, Ohio Division of Geological Survey.
[3] 1, As received; 2, moisture free; 3, moisture and ash free; 4, dry unit coal; 5, moist unit coal.

experimental plant was erected in Fearing Township near the village of Whipple, where there is cannel coal in many places. This operation was not too successful, and the plant shut down when petroleum became generally available.

The Pittsburgh coal certainly cannot be considered an important resource for the county under present conditions, and it is difficult to see how it could ever contribute to the economic well-being of the area without the development of unforeseen processes for its utilization.

## MEIGS CREEK (NO. 9) (SEWICKLEY) COAL

Economically, the most important coal in Washington County is the Meigs Creek. This bed has been mined since the days of the early settlers and constitutes the largest known mineable resource in the county. Resources of this seam are confined largely to the north and east-central parts of the county (fig. 6), with the exception of small areas in the west along the Athens County line.

A clay or poorly bedded shale parting commonly divides the Meigs Creek into two major benches. This parting appears to be laterally persistent over most of Aurelius, northern Salem, Liberty, and Ludlow Townships, where a thickness of 12 to 24 inches, or even greater in a few places, is not unusual. Figure 6 shows isopachs drawn on this bed with the major parting removed, so that the thickness represents only the bright blocky coal. The following sections illustrate the relationship of the coal and parting:

O.G.S. 15274, Aurelius Township, C of the S½ of the SW¼ sec. 16, Lower Salem 7½- and Macksburg 15-minute quadrangles. Section measured in abandoned strip mine. Measured by H. R. Collins and B. E. Smith.

TABLE 4.—*Oil-content yields of Pittsburgh (No. 8) coal in Washington County, Ohio*

| Township | OGS file no. | EES no.[1] | Condition[2] | Charge (g) | Yields | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | cc/100g charge | | % by weight | | gal/ton | |
| | | | | | Oil[3] | Water | Spent shale (coke) | Gas and loss | Oil | Water |
| Ludlow | 502-1 | 98 | 1 | 200.0 | 11.4 | 5.3 | 69.5 | 13.8 | 27.3 | 12.7 |
| | | | 2 | 196.7 | 11.59 | 3.7 | 70.7 | 14.01 | 27.8 | 8.9 |
| Ludlow | 502-2[4] | 99 | 1 | 300.0 | 1.5 | 6.7 | 88.5 | 3.3 | 3.6 | 16.1 |
| | | | 2 | 292.6 | 1.54 | 4.3 | 90.7 | 3.46 | 3.7 | 10.3 |
| Ludlow | 503 | 100 | 1 | 200.0 | 6.0 | 11.4 | 65.3 | 17.3 | 14.4 | 27.3 |
| | | | 2 | 187.1 | 6.41 | 5.3 | 69.8 | 18.49 | 15.4 | 12.7 |

[1] Engineering Experiment Station, The Ohio State University.
[2] 1, As received or air dried; 2, moisture free.
[3] Second decimal place is entirely a product of recalculation on moisture-free sample and does not indicate reproducibility of distillation method used.
[4] Sample of coal shale 1 ft 4 in thick immediately below sample 502-1. See OGS 6837, p. 68.

| | ft | in | ft | in |
|---|---|---|---|---|
| *Units 22 and 23 omitted* | | | | |
| Coal, MEIGS CREEK, base elevation 866 feet | | | | |
| 21. Coal, bright, blocky; upper bench | 2 | 6 | 193 | 8 |
| 20. Clay, medium- to dark-gray; coaly streaks | 3 | 7 | 191 | 2 |
| 19. Coal, bright, blocky; lower bench | 3 | 0 | 187 | 7 |
| *Units 1 through 18 omitted* | | | | |

O.G.S. 7291, Adams Twp., x = 2,262,700 feet, y = 570,700 feet, Lowell 7½- and Beverly 15-minute quadrangles. Description of sample taken in mine of Felix Coal Company ½ mile SE of Coal Run. Measured by J. Hyde. O.G.S. chemical analysis 287 (table 5), by N. W. Lord and E. E. Somermeier.

| | ft | in | ft | in |
|---|---|---|---|---|
| Coal, MEIGS CREEK | | | | |
| Coal, sampled | 0 | 6 | 3 | 5 7/8 |
| Smut; some pyrite and shale; sampled | 0 | 3/8 | 2 | 11 7/8 |
| Coal, including pyrite and smut; sampled | 1 | 4 | 2 | 11 1/2 |
| Coal, with numerous pyrite and shale partings; rejected | 0 | 3 3/4 | 1 | 7 1/2 |
| Coal, with two pyrite partings; sampled | 0 | 11 3/4 | 1 | 3 3/4 |
| Coal, forming floor in entries; rejected | | 4 | | 4 |

O.G.S. 12538, Adams Twp., x = 2,277,800 feet, y = 568,400 feet, Lowell 7½- and Beverly 15-minute quadrangles. Description of sample taken in Pfile Mine on the left fork of Cats Creek, 2 miles N of Lowell. Measured by A. W. Seabright. O.G.S. chemical analysis 496 (table 5), by D. J. Demorest.

| | ft | in | ft | in |
|---|---|---|---|---|
| Coal, MEIGS CREEK | | | | |
| Coal, sampled | 0 | 9 3/16 | 2 | 10 11/48 |
| Coal, bone; rejected | 0 | 5/8 | 2 | 1 1/24 |
| Pyrite, rejected | 0 | 1/6 | 2 | 5/12 |
| Coal, mother coal and bone coal, rejected | 0 | 3 1/4 | 2 | 1/4 |
| Coal, bony; sampled | 1 | 5 5/16 | 1 | 8 1/2 |
| Pyrite, sampled | 0 | 1/16 | 0 | 3 3/16 |
| Coal, bony; sampled | 0 | 3 | 0 | 3 |

O.G.S. 11766, Aurelius Twp., NW¼ sec. 28, Lower Salem 7½- and Macksburg 15-minute quadrangles. Description of sample taken one mile southwest of Elba. Measured by J. E. Hyde. O.G.S. chemical analysis 286 (table 5), by N. W. Lord and E. E. Somermeier.

| | ft | in | ft | in |
|---|---|---|---|---|
| Coal, MEIGS CREEK | | | | |
| Coal, lower part of upper bench; rejected | 0 | 9 1/2 | 5 | 1/8 |
| Shale and clay; rejected | 1 | 3 | 4 | 3 5/8 |
| Coal, sampled | 0 | 8 3/4 | 3 | 5/8 |
| Shale, rejected | 0 | 5/8 | 2 | 3 7/8 |
| Coal, sampled | 2 | 3 1/4 | 2 | 3 1/4 |

W. H. Smith and others (1952) calculated an original resource tonnage of 512,353,000 for the Meigs Creek in Washington County. These authors show considerable area south of the Muskingum River in Adams, Waterford, and Watertown Townships as being underlain by mineable coal. Isopachs drawn on this bed (fig. 6) by the authors indicate the possibility of less coal in these three townships than previously thought, but the lack of core records south of the Muskingum River seriously hampers any attempt to closely delimit the area of mineable Meigs Creek coal, and no new resource tabulation is warranted.

Slightly over 3,000,000 tons of coal have been produced in Washington County in the period 1867-1968. Virtually all of it was mined from the Meigs Creek, but when this figure is compared to an original resource figure of 512,353,000 tons it is obvious that there is a substantial resource of this coal. However, federal and state mining laws, which require that a barrier pillar of unmined coal be left surrounding a well, limit the actual mineable resources in areas having large numbers of oil and gas wells.

The Meigs Creek coal has been mined most intensively in Aurelius Township, where strip mining and, to a minor extent, augering has accounted for most of the tonnage removed. There were a number of small underground mines in the county, but their production was relatively limited. The two largest of these were the Peerless #2 in sec. 22, Aurelius Township, and the Keever slope in Waterford Township on Sugar Run about halfway between Beverly and Coal Run. The mined-over areas for these two locations

TABLE 5.—*Analyses of the Meigs Creek (No. 9) coal in Washington County, Ohio*

| Township | OGS file no. | Kind[1] | Source[2] | Condition[3] | Proximate analysis | | | Ultimate analysis | | | | | | Heat value | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Moisture | Volatile matter | Fixed carbon | Ash | Sulfur | Hydrogen | Carbon | Nitrogen | Oxygen | Calories | Btu |
| Adams | 287 | 1 | 2 | 1 | 2.95 | 37.47 | 46.69 | 12.89 | 5.55 | 5.05 | 65.88 | 0.92 | 9.71 | 6803 | 12,245 |
| | | | | 2 | | 38.61 | 48.11 | 13.28 | 5.72 | 4.86 | 67.88 | 0.95 | 7.31 | 7010 | 12,617 |
| | | | | 3 | | 44.52 | 55.48 | | 6.00 | 5.60 | 78.27 | 1.10 | 8.43 | 8083 | 14,549 |
| | | | | 4 | | 42.73 | 57.27 | | | | | | | 8303 | 14,945 |
| | | | | 5 | 3.55 | 41.22 | 55.23 | | | | | | | 8008 | 14,414 |
| Adams | 496 | 1 | 2 | 1 | 2.72 | 41.16 | 44.57 | 11.55 | 4.48 | 6.83 | 67.07 | 1.04 | 9.03 | 6850 | 12,330 |
| | | | | 2 | | 42.31 | 45.82 | 11.87 | 4.61 | 6.71 | 68.95 | 1.07 | 6.79 | 7042 | 12,675 |
| | | | | 3 | | 48.01 | 51.99 | | 5.23 | 7.61 | 78.25 | 1.21 | 7.70 | 7990 | 14,382 |
| | | | | 4 | | 46.68 | 53.32 | | | | | | | 8168 | 14,720 |
| | | | | 5 | 3.20 | 45.19 | 51.61 | | | | | | | 7907 | 14,232 |
| Aurelius | 286 | 1 | 2 | 1 | 3.40 | 37.95 | 49.07 | 9.58 | 5.03 | 5.31 | 68.33 | 0.90 | 10.85 | 7083 | 12,749 |
| | | | | 2 | | 39.28 | 50.80 | 9.92 | 5.21 | 5.10 | 70.73 | 0.93 | 8.11 | 7332 | 13,198 |
| | | | | 3 | | 43.61 | 56.39 | | 5.78 | 5.66 | 78.53 | 1.03 | 9.00 | 8139 | 14,651 |
| | | | | 4 | | 42.12 | 57.88 | | | | | | | 8317 | 14,970 |
| | | | | 5 | 3.91 | 40.48 | 55.61 | | | | | | | 7991 | 14,384 |

[1] 1, Channel (mine); 2, channel (outcrop).
[2] 1, U.S. Bureau of Mines and/or U.S. Geological Survey; 2, Ohio Division of Geological Survey.
[3] 1, As received; 2, moisture free; 3, moisture and ash free; 4, dry unit coal; 5, moist unit coal.

probably did not exceed 30 and 20 acres, respectively.

Considerable work was done on the chemical and physical properties and the washability characteristics of this coal by Krumin (1957). None of his samples were collected within the boundaries of Washington County, but interested parties may wish to consult his study and that of W. H. Smith and others (1952) for additional data on this coal. Similarly, although it does not deal directly with Washington County, a report on the petrography of the Meigs Creek coal by Cady and Smith (1955) will be of interest to some readers. Table 5 gives the available Meigs Creek chemical data for the county.

## UNIONTOWN (NO. 10) COAL

Uniontown coal 14 inches thick or more is found in isolated pods at a number of localities in the county (fig. 8). The area of thickest known coal is in sec. 18, Fairfield Township, where there is a single record of 45 inches of coal. However, the coal thins to less than 14 inches in the immediately surrounding area. In Wesley Township, Uniontown coal 24 to 36 inches in thickness is found; laterally, as elsewhere in the county, the coal thins to below the 14-inch resource limit in a short distance.

The Uniontown is bony to shaly in many places and is commonly separated into two or more benches by rather persistent clay, shale, or limestone partings. The general nature of the bed is illustrated by the following stratigraphic section:

O.G.S. 6649, Newport Twp., NW¼ sec. 17, Belmont 7½- and Marietta 15-minute quadrangles. Measured by W. H. Smith.

| | ft | in | ft | in |
|---|---|---|---|---|
| Coal, UNIONTOWN, base elevation 812 feet | | | | |
| Coal, blocky, bright, hard; upper contact concealed | 0 | 8 | 9 | 11 |
| Limestone, coaly | 0 | 2 | 9 | 3 |
| Coal, blocky, bright, hard | 0 | 11 | 9 | 1 |
| Clay shale, gray | 0 | 2½ | 8 | 2 |
| Coal, bony, hard | 0 | ¼ | 7 | 11½ |
| Coal, blocky, bright, medium- to thick-banded | 0 | 5¼ | 7 | 11¼ |

There have been numerous attempts to mine this coal for local use, but no large operations were seen by the authors or reported by the local inhabitants. Small mine dumps were noted at several localities in Decatur, Fairfield, and Wesley Townships.

An original resource tonnage estimate of 502,620,000 for the Uniontown coal was made by Denton (1960, p. 20) on the basis of very few data. This bed is of only minor importance in terms of coal resources, and no new resource tonnages were calculated, but it is estimated roughly by the authors that there is less than 100,000,000 tons of Uniontown coal over 14 inches thick in Washington County. This sizable reduction of the estimate given by Denton is based largely on new data indicating that only Decatur, Fairfield, and Wesley Townships contain sufficient coal over 14 inches thick to constitute a resource. There is no known Uniontown coal of resource thickness in Barlow, Belpre, Dunham, Independence, Muskingum, Warren, or Watertown Township and no significant amount of resource coal in Fearing, Grandview, Lawrence, Liberty, Ludlow, Newport, or Salem Township.

## WAYNESBURG (NO. 11) COAL

Denton (1960, p. 18) reported that the Waynesburg coal may have a potential resource of 73,000,000 tons in Ludlow, Marietta, and Waterford Townships. Correlations established by the authors indicate that the coals tabulated by Denton were erroneously identified as Waynesburg by both earlier and subsequent workers. Waynesburg coal of resource thickness was not found in the county, and the authors assigned no resources to this coal.

## UNNAMED COAL

A coal identified by many workers in eastern Ohio as the Waynesburg "A" is found in mineable thickness in easternmost Grandview Township. The authors consider that this coal is probably not the Waynesburg "A" but a higher unnamed unit. The bed ranges from bright and blocky coal to shaly coal and shale, and clay partings are not uncommon. The following section illustrates the general nature of the unit:

O.G.S. 8159, Grandview Township, NW¼ of the SW¼ sec. 10, New Matamoras 7½- and New Matamoras 15-minute quadrangles. Measured by A. T. Cross.

| | ft | in | ft | in |
|---|---|---|---|---|
| *Approximately 138 feet of section omitted* | | | | |
| Coal, base elevation 877 feet | | | | |
| Coal, soft, somewhat shaly | 1 | 7 | 40 | 4 |
| Coal, shaly parting | 0 | ½ | 38 | 9 |
| Coal, soft, shaly | 0 | 8 | 38 | 8½ |
| Coal, blocky; thin shaly parting in middle | 0 | 4 | 38 | ½ |
| Coal, shaly | 0 | ½ | 37 | 8½ |
| Coal, soft, blocky | 0 | 8 | 37 | 8 |
| Coal, hard, blocky | 1 | 1 | 37 | 0 |
| *Approximately 30 feet of section omitted* | | | | |

This coal is found to be thickest in secs. 3 and 10 in the northeast corner of Grandview Township; the coal thins westward to less than 14 inches in a short distance. Nine to 10 square miles are underlain by 14 inches or more of this coal. Denton's (1960) estimate of nearly 37,000,000 tons of coal for this bed seems to be reasonable.

Smith (1951, p. 46) reported that samples collected from this seam in Jackson Township, Monroe County, about a quarter of a mile east of the Washington County line, yielded from 9.6 to 21.6 gallons of oil per ton, figures that may be low because the sample was weathered. The sampled increments at this locality had 16.9 to 39.6 percent ash content.

## WASHINGTON (NO. 12 COAL)

Small isolated pockets of Washington coal, 14 inches thick or more, are found in Dunham, Fearing, and Marietta Townships (fig. 15). At none of these localities does the coal exceed 25 inches in thickness. This coal is bright and blocky to bony in character and is broken by clay or shale partings in many places.

In eastern Marietta and southeastern Fearing Townships there are approximately 6 square miles underlain by Washington coal over 14 inches thick. A resource figure of about 10,000,000 tons is reasonable for this area. The other four locations where this coal was found in resource thickness were of such small area that an attempt to estimate the tonnage would be meaningless.

# CLAY AND SHALE RESOURCES OF WASHINGTON COUNTY

by

David K. Webb, Jr.

## INTRODUCTION

The ceramic industry in Washington County dates back to the late 1700's. The first use of brick in Ohio appears to have been in the construction of Campus Martius at Marietta. This fortification was built in 1788-1791, and most of the houses were provided with brick chimneys. The bricks were made in the immediate vicinity, and brick-making became a regular occupation in this settlement as early as 1797. In later years face brick was manufactured in the Marietta area from the Creston Reds. In the 1950's fire clay and shale were mined near Marietta by the Briggs Gravel Company and the Marietta Concrete Corporation, respectively. The fire clay was reportedly used for furnace lining and the shale for the production of a type of lightweight expanded shale aggregate sold under the brand name of Beslite. There has been no reported clay or shale production in recent years.

Washington County does not possess the refractory clays upon which large segments of the industry have been based in other areas of the state. This county does, however, have a generous supply of red-burning clays and shales. Several of these units appear to be suitable for the manufacture of structural clay products and garden pottery.

In order to encourage and aid expansion of the clay and shale industry in the county, material from several stratigraphic units was subjected to elementary ceramic testing. The results of these tests and the potential uses are presented on the following pages. The results are intended merely to be suggestive. Before large sums of money are invested, properties in question should be evaluated by means of an adequate drilling program. The prospective raw material should be subjected to more sophisticated tests and if possible pilot scale tests should be made.

## PREVIOUS WORK

Stout and others (1923, p. 460-474) included the coal formation clays of Washington County in their general discussion of the stratigraphy, distribution, and economic aspects of the Conemaugh, Monongahela, and Dunkard Groups. None of the clays are considered by those authors to have much of a future other than as raw materials for common products and bloated material for concrete aggregate. No analyses are provided for Washington County material.

Lamborn and others (1938, p. 218-219) reported the test results from a sample of Creston Reds from the pit of the Marietta Shale Brick Company at Marietta (see p. 110 of this report). In addition to a chemical analysis, the firing behavior and properties in the green state are given. The results indicate that a good salt glaze can be produced at both 2100°F and 2050°F. Although the material has been utilized for face brick only, common brick, drain tile, and hollow tile are suggested as additional possibilities. The best firing range is reported to be cone 08 to cone 3.

Everhart and others (1958) reported the results of bloating tests on another sample from near Marietta. Their tests indicate that a specific gravity of less than 1.5 is developed by flash firing at less than 2400°F, and the sample therefore shows promise as a raw material for lightweight aggregate production.

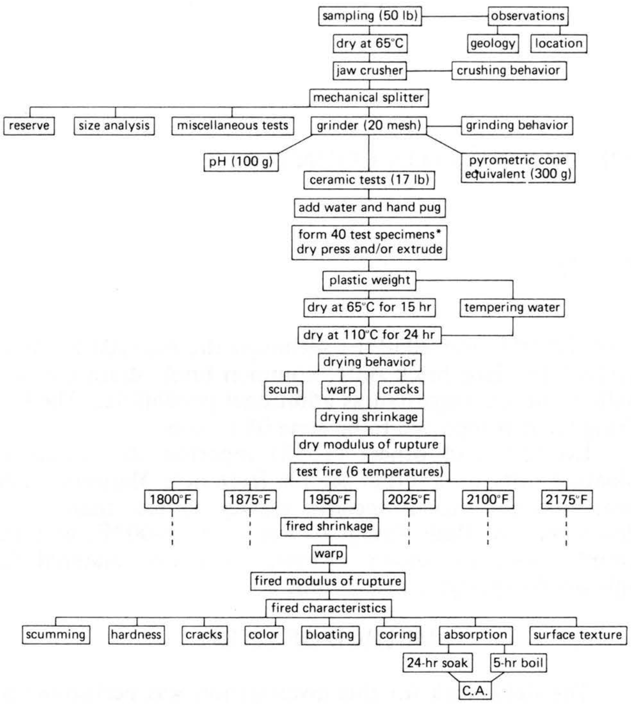
## METHOD OF STUDY

The field work for this investigation was performed by staff members of the Ohio Division of Geological Survey between April 1963 and October 1965. Samples were collected from mines, road cuts, and drill holes and are considered to be representative. An attempt was made in every case to remove highly weathered, slumped, or contaminated material from an exposure prior to sampling. A jeep-mounted auger was employed to sample three Pleistocene lake terraces at depth.

Most of the analytical work and ceramic tests were accomplished at the laboratories of the Ohio Division of Geological Survey and The Ohio State University Department of Ceramic Engineering. Dr. J. O. Everhart of the Department of Ceramic Engineering critically read the manuscript and made certain pieces of testing equipment available for the authors' use during the laboratory determinations. Test procedures are based primarily upon those described by Klinefelter and Hamlin (1957). The criteria used in evaluating the clays and shales for possible commercial utilization were proposed by Hamlin (1960). Figure 36 illustrates the scheme followed in evaluating the clay and shale resources of Washington County.

The value of a clay cannot be completely determined by laboratory-scale tests. Such tests do have value, however, because in many cases they provide the means of differentiating between clays which are definitely unsatisfactory for a given use and those which warrant further testing. They are also useful in predicting possible uses and quality of products. With this philosophy in mind, the required tests and observations were made to provide information on the following properties: tempering water, plasticity, workability, drying defects, linear drying shrinkage, wet strength, dry strength, linear fired shrinkage, absorption, hardness, fired color, fired strength, and firing defects.

Because of the continual demand for information on the chemical characteristics of Ohio clays and shales, chemical analyses are provided for three samples. The Meigs Creek clay, Creston Reds, and a Pleistocene lake clay were selected for a combination of reasons, including geographic




*Note: To permit a more comprehensive evaluation of the clays to be made, one sample each of the major types was formed into test bars by de-aired extrusion. Samples formed by de-aired extrusion include Creston Reds (#84-0472), Meigs Creek clay (#84-0463), Washington clay (#84-0456), and Pleistocene lake clays (#84-0626 and #84-0468). Samples #84-0468, #84-0472, and #84-0626 were evaluated by both methods.

FIGURE 36.—Scheme used to evaluate the clays and shales of Washington County, Ohio.

location, potential reserves, persistence, thickness, and uniformity. American Society for Testing and Materials methods were used where applicable, and each sample was analyzed at least two times for greater accuracy. The composition is calculated on an as-received basis, and the average of the two values is reported. Partial analyses of four other samples were made by atomic absorption spectrophotometry and are included in the chemical analyses presented in table 6. In the interest of completeness, previously published data from Ohio Division of Geological Survey Bulletin 39 are included in this table.

## GENERAL DISCUSSION

Structural clay products are produced from a wide variety of clays, and the properties of the raw material are more or less important, depending on the product desired and the method of processing. Because the stiff-mud extrusion process is the most common method of fabrication, plasticity is probably the most important property of the raw material. Very plastic clay tends to laminate when extruded; nonplastic clays in many cases are difficult to extrude in a smooth column. Clays intermediate between these extremes are desirable for structural clay products. Drying characteristics are important to the extent that the clay should dry uniformly at a reasonable rate without warping or cracking. An adequate green strength must be developed to permit the ware to be handled in the unfired wet and dry states. The importance of fired color differs from one structural product to another, and the natural color of the fired body can be augmented by the addition of pigments. The blending of clays to produce structural clay products has become fairly common practice in recent years. It is possible in some cases to blend together two or more clays, by themselves unsatisfactory but which have mutually beneficial properties, to provide a satisfactory product.

Whiteware clays must fire white; this criterion eliminates all Washington County clays and shales from consideration for this use.

The evaluation of lightweight aggregate clays requires a different testing procedure than that used for other structural clay products. No clays were specifically tested for lightweight aggregate use during the course of this investigation. The occurrence of bloating is noted, however, and it is believed that these observations will be of value in any search for lightweight aggregate raw material.

Fired color and workability are the most critical properties when evaluating pottery clays. If the ware is formed by throwing or jiggering, the clay must have above-average plasticity. As a general rule, the more plastic clays have the better slip-casting properties. Most pottery clays are made from a blend of clays and fluxing materials, so workability, firing characteristics, colors, and maturing temperatures can be controlled to a limited extent by selecting the proper clays.

The most important property to be considered in evaluating a potential refractory clay is its ability to

TABLE 6.—*Chemical analyses of selected clays and shales from Washington County, Ohio*

| Sample no.[1] | Loss | | $SiO_2$ | $Al_2O_3$ | $Fe_2O_3$ | CaO | MgO | $TiO_2$ | $P_2O_5$ | $Na_2O$ | $K_2O$ | MnO | S | C | | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 105°C | Ignition | | | | | | | | | | | | Total | Inorganic | |
| 84-0455 | *[2] | * | * | 19.6 | 8.6 | 0.47 | 1.44 | 1.03 | * | 0.54 | 2.75 | * | * | * | * | Shale over 100' smut |
| 84-0460 | * | * | * | 16.3 | 10.1 | 7.20 | 1.65 | 0.84 | * | 0.59 | 2.80 | * | * | * | * | Creston Reds |
| 84-0461B | 2.06 | 7.25 | 56.56 | 21.46 | 6.20 | 0.26 | 1.50 | 0.84 | 0.20 | 0.33 | 3.23 | 0.027 | 0.49 | 0.33 | 0.012 | Meigs Creek clay |
| 84-0471 | * | * | * | 16.4 | 7.5 | 3.96 | 1.66 | 0.82 | * | 0.33 | 2.38 | * | * | * | * | Washington clay |
| 84-0473 | 1.75 | 8.04 | 51.94 | 19.06 | 8.28 | 4.20 | 1.86 | 0.76 | 0.26 | 0.50 | 3.12 | 0.090 | 0.012 | 0.84 | 0.81 | Creston Reds |
| 84-0625 | * | * | * | 20.3 | 8.2 | 0.96 | 1.47 | 1.09 | * | 0.33 | 3.43 | * | * | * | * | Pleistocene lake clay |
| 84-0626 | 1.35 | 6.45 | 61.56 | 15.52 | 6.54 | 2.23 | 1.82 | 0.75 | 0.14 | 0.66 | 2.78 | 0.082 | 0.015 | 0.79 | 0.53 | Pleistocene lake silt |
| 49[3] | 1.73 | * | 55.80 | 18.65 | 8.16 | 2.08 | 1.95 | 1.45 | 0.19 | 0.93 | 3.33 | trace | * | * | * | Creston Reds |

[1] Samples 84-0455, 84-0460, 84-0471, and 84-0625 analyzed by atomic absorption spectrophotometry.
[2] Not analyzed for.
[3] Lamborn and others, 1938, p. 218.

withstand high temperatures. None of the Washington County clays tested have a pyrometric cone equivalent sufficiently high to be rated as a refractory clay.

## SUMMARY

The clays and shales of Washington County are most suitable for use in the manufacture of low-cost products with an attendant low mining cost, low firing temperature, and standard method of production. The 33 samples evaluated represent material from 16 townships and 10 stratigraphic units. The test suite includes 8 samples of shale and mudstone, 10 of underclay, and 12 of surface clay and silt. The test results suggest that there is raw material in the county potentially suitable for use in the manufacture of building brick, face brick, drain tile, hollow tile, chimney tile, wall tile, floor tile, artware, earthenware, sewer pipe, conduit, lightweight aggregate, modeling clay, and bonding clay. Most of the samples matured at 2025°F to 2100°F; only 7 required higher temperatures. All samples fired to a red-brown color at maturity. Absorption ranged from 0.6 to 13.9 percent, fired shrinkage from 1.2 to 10.5 percent, and modulus of rupture from 664 psi to 7430 psi. Acidity of samples differed considerably, the pH ranging from 3.4 to 9.6. Of the several samples chemically analyzed, none had a high alumina content; 21.46 percent $Al_2O_3$ was the highest value reported. Pyrometric cone equivalent (PCE) values ranged from cone 5 to cone 15, none being sufficiently high for the sample to be rated as a refractory clay. Comparison of the data for extruded test bars with those for dry pressed bars suggests that forming by extrusion causes an increase in dry strength and dry shrinkage and commonly a decrease in absorption. The effect of extrusion on fired hardness, color, strength, and shrinkage was inconclusive.

On the basis of versatility and reserves, the Meigs Creek clay appears to have the most potential of the bedrock units. It shows some promise of being suitable for the manufacture of most structural clay products, with the exception of terra cotta. It is questionable, however, whether the plasticity is high enough for the manufacture of most pottery. As with most rock units in the county, this clay does not have a consistent character; it ranges from a moderately plastic nonbedded clay to a sandy mudstone. It is calcareous in places and commonly silty and iron stained. The thickness ranges from a few inches to 15 feet. In Aurelius, Liberty, and Ludlow Townships where it was tested it averages a little over 7 feet in thickness. The unit is generally thinner in the townships to the south and west. Immediately below the Meigs Creek clay there is commonly a silty shale which might be mined and used in conjunction with the clay. The one sample of this shale tested had a relatively long maturing range and in general appeared to be suitable for the manufacture of the same suite of products as the clay. The coal which overlies the clay is currently being stripped in the county, and, should the demand ever arise, some economic advantage might be gained by recovering both the coal and clay in a single operation.

The Creston Reds are present at the surface in most of the southern and eastern portions of the county. The mudstone facies, which averages about 38 feet in thickness, is best represented in Barlow, Belpre, Decatur, Dunham, Fairfield, Marietta, Newport, Warren, and Watertown Townships. The reserve of Creston Reds is as large or larger than that of the Meigs Creek clay, but the presence of carbonate, in the form of limy nodules, thin limestone beds, and as a cementing agent, limits its use. If the carbonate is finely divided and of sufficient quantity, the firing range will be reduced and in red-burning clays the fired color will be lightened. If the carbonate is present in particles of sufficient size, it will hydrate after firing and cause "lime pop-outs." As a unit the Creston Reds displays, both laterally and vertically, a highly different character from place to place. West and southwest of Marietta the lithology is predominantly mudstone similar to that of the type area. In the northeastern portion of the county the unit is represented by interbedded sandstones, shales, mudstones, and rubbly limestones. Some of the samples tested do show promise for use in the manufacture of building brick and tile, and there is a history of use of the Creston Reds in Marietta Township for the manufacture of face brick. Test results (Lamborn and others, 1938, p. 218-219) on a sample of Creston Reds from this township follow (p. 110) the analyses made for this report. Because of the character of the unit, however, it is recommended that a detailed sampling and testing program precede any mining or manufacturing venture based upon this material.

The Pleistocene lake silts appear to be suited for the manufacture of structural clay products and possibly some artware. The geometry and extent of these deposits are not known in sufficient detail to estimate the reserves, but the terraces sampled by augering were in excess of 30 feet thick; bedrock was not encountered in any of the three holes. The material referred to as Minford "silt" differs considerably at various places in texture, mineralogy, thickness, and ceramic properties. The very clayey phase warrants some consideration as a raw material for the manufacture of lightweight aggregate; some of the very sandy deposits have been used in the past as sources of molding sand. The silty phase is not especially well suited for anything, but it is possible that building bricks could be manufactured from some of it.

Three shales were tested and all showed some degree of promise. The shales are commonly thicker than the underclays, but they are also patchy in occurrence and quite different at various places. Inability to correlate these units over any distance seriously hampers attempts to evaluate the reserves of the county, but there is no reason to believe that sufficient tonnage could not be found if the demand existed.

The clay under the Washington coal is relatively thick and widespread. It was sampled in several places, but its relatively high carbonate content and low plasticity do not recommend it for most uses. The Little Waynesburg underclay was tested in only one locality, but the results were favorable enough to suggest that additional testing might be warranted.

The one sample of recent alluvium evaluated was very silty and sandy; the attendant low plasticity, high absorption, and high maturing temperature detract from its value as a ceramic raw material.

In general the clays and shales of Washington County are low in alumina and high in fluxes. They are therefore not suitable for the manufacture of high-grade clay products. It appears that any resurrection of the industry in the county in the near future will have to be based upon the manufacture of low-cost common clay products, lightweight aggregate, or nonrefractory nonwhite specialty clays.

## SAMPLE DATA AND TEST RESULTS

Sample descriptions and test results are combined and presented separately for each sample. These data are arranged by sample number in numerical order. The first two digits of each sample number identify the county; Washington County is indicated by the numerical prefix "84." The last four digits identify the sample. Although the Division of Geological Survey assigns sample numbers in consecutive order, the sample numbers for a given county or report are not necessarily consecutive; some deposits are sampled but never evaluated and some areas are sampled at several different times. Where the region has been divided into sections, the sample localities are generally located to the nearest 1/16th of a section. In those areas that have not been sectioned, sample sites are located by the Ohio Coordinate System, south zone. Locations of samples within the county are indicated in figure 37.

The recorded linear fired shrinkage value refers only to the shrinkage due to firing; for total shrinkage it is necessary to add the linear drying shrinkage value. The firing shrinkage values reported for the dry pressed specimens may be higher than could be achieved in commercial production where higher forming pressures and de-airing would be possible. Abbreviations used are:

| | |
|---|---|
| abs. | absorption (24-hour or 5-hour) |
| b | bloating |
| C.A. | coefficient of absorption |
| co | coring |
| cr | cracking |
| L.S. | linear shrinkage |
| m | mature |
| M.O.R. | modulus of rupture |
| NA | not applicable |
| ND | nondisaggregating sample |
| o | overfired |
| p | popouts |
| pi | pimples |
| s | scum |
| sl | slight(ly) |
| SR | state route |
| TR | township route |
| u | underfired |
| w | warping |

In listing potential uses of a sample the investigator was guided by the following assumptions: (1) Scumming could be economically and effectively eliminated by use of an antiscum agent such as barium carbonate. (2) There is some demand for a red-brown fired color in the product. (3) A maturing temperature 75°F higher than that recommended by Klinefelter and Hamlin was acceptable.

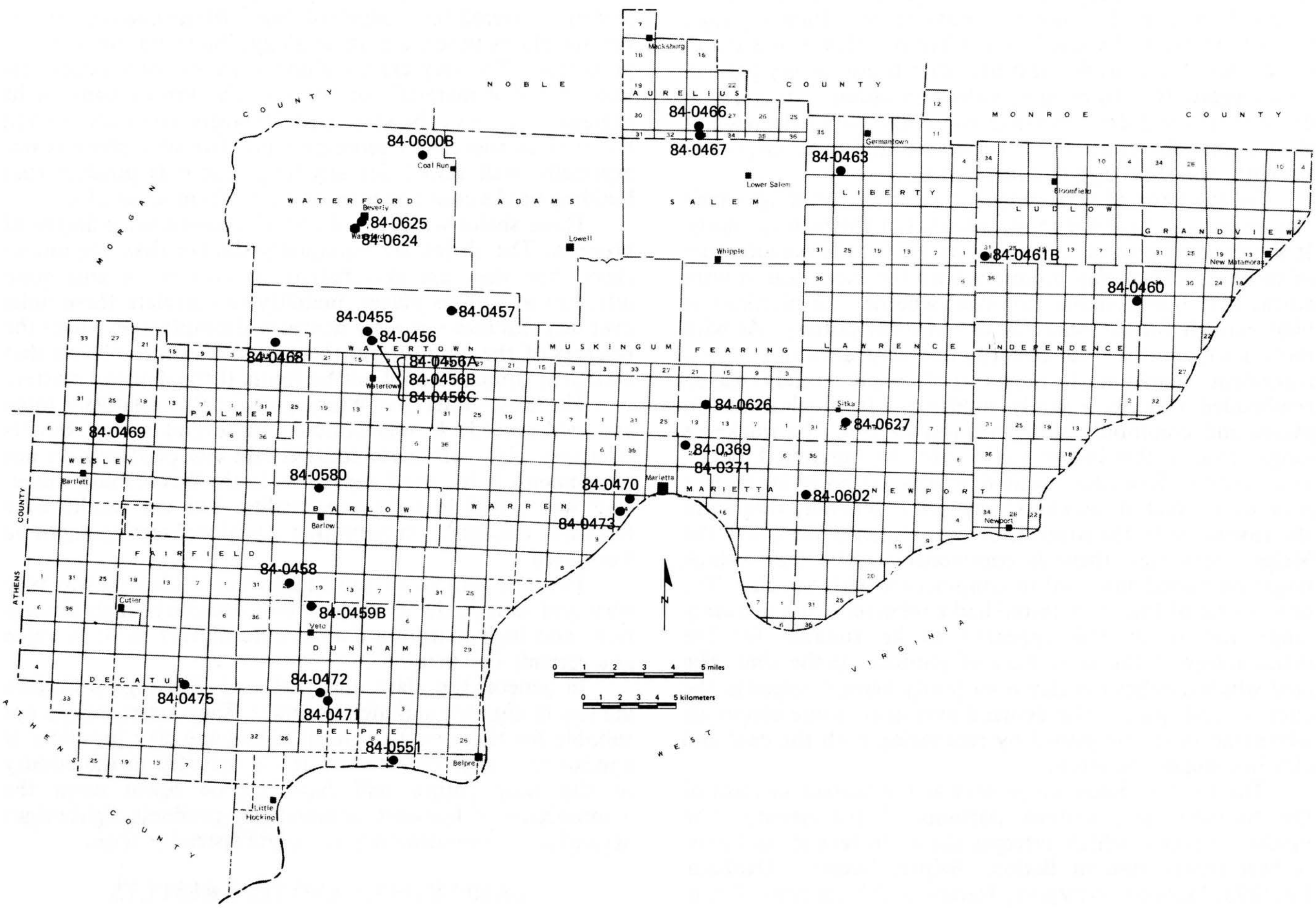



FIGURE 37.—Clay and shale sample localities in Washington County, Ohio.

*Sample no.:* 84-0369
*County:* Washington
*Quadrangle (7½'):* Marietta
*Township:* Marietta
*Section or grid coordinates:* SE¼ of NW¼ sec. 24
*Site:* Highway test core just N of Marietta
*Lithology:* Mudstone, light-greenish-gray to dark-reddish-gray; silty and calcareous in places
*Stratigraphy:* Creston Reds
*Thickness:* 59 ft
*Elevation of base:* 807 ft
*Type of sample:* Core of upper 9 ft (see sample 84-0371 for data on bottom 20 ft)
*Division of Geological Survey stratigraphic section:* NA

*Ceramic characteristics*

*Forming method used:* Dry press at 1200 psi
*Tempering water:* 11.1%
*Plasticity and workability:* Plasticity moderate
*Wet strength:* Satisfactory
*Dry behavior:* Satisfactory
*Linear drying shrinkage:* 1.0%
*Dry strength:* 109 psi

*Slow-fired properties*

| Temp. (°F) | 24 abs. (%) | 5 abs. (%) | C.A. | L.S. (%) | M.O.R. (psi) | Hard. (Mohs) | Color | Remarks |
|---|---|---|---|---|---|---|---|---|
| 1800 | 11.7 | 13.2 | 0.89 | 0.6 | 590 | 3 | light orange brown | |
| 1875 | 10.0 | 11.6 | 0.86 | 1.8 | 1030 | 4½ | orange brown | |
| 1950 | 7.7 | 9.5 | 0.81 | 3.5 | 1500 | 6 | red brown | |
| 2025 | 4.1 | 5.8 | 0.71 | 4.3 | 2570 | 7 | red brown | m |
| 2100 | 2.4 | 4.3 | 0.56 | 4.4 | 3100 | 8- | dark red brown | m |
| 2175 | 1.3 | 3.2 | 0.41 | 2.8 | 2590 | 8- | dark red brown | w, o |

*Particle-size analysis:* Sand and larger %: ND Silt %: ND Clay %: ND
*pH:* 9.1
*Pyrometric cone equivalent:*
*Other test results:*
*Present and past use:*
*Potential use:* Building brick, face brick, hollow tile, wall tile, drain tile
*Remarks:* Low dry strength

*Sample no.:* 84-0371
*County:* Washington
*Quadrangle (7½'):* Marietta
*Township:* Marietta
*Section or grid coordinates:* SE¼ of NW¼ sec. 24
*Site:* Highway test core just N of Marietta
*Lithology:* Mudstone, dark-red and reddish-gray, calcareous
*Stratigraphy:* Creston Reds
*Thickness:* 59 ft
*Elevation of base:* 758 ft
*Type of sample:* Core of lower 20 ft (see sample 84-0369 for data on top 9 ft)
*Division of Geological Survey stratigraphic section:* NA

*Ceramic characteristics*
*Forming method used:* Dry press at 1200 psi
*Tempering water:* 10.6%
*Plasticity and workability:* Satisfactory
*Wet strength:* Satisfactory
*Dry behavior:* Satisfactory
*Linear drying shrinkage:* 1.4%
*Dry strength:* Satisfactory

*Slow-fired properties*

| Temp. (°F) | 24 abs. (%) | 5 abs. (%) | C.A. | L.S. (%) | M.O.R. (psi) | Hard. (Mohs) | Color | Remarks |
|---|---|---|---|---|---|---|---|---|
| 1800 | 11.8 | 13.0 | 0.91 | 0.2 | 950 | 3½ | light orange brown | |
| 1875 | | | | | | | | |
| 1950 | 8.9 | 10.6 | 0.84 | 1.8 | 1250 | 5 | orange brown | |
| 2025 | | | | | | | | |
| 2100 | 4.5 | 6.3 | 0.71 | 4.1 | 3030 | 6½ | dark red brown | sl s, p, m |
| 2175 | | | | | | | | |

*Particle-size analysis:* Sand and larger %: ND Silt %: ND Clay %: ND
*pH:* 9.6
*Pyrometric cone equivalent:*
*Other test results:*
*Present and past use:*
*Potential use:* Building brick, drain tile

*Sample no.:* 84-0455
*County:* Washington
*Quadrangle (7½'):* Watertown
*Township:* Watertown
*Section or grid coordinates:* x = 2,244,900 ft, y = 541,100 ft
*Site:* Road cut on E side of SR 76, approximately 1 mi N of Watertown
*Lithology:* Shale, medium- to dark-gray, silty; sandy stringers and ironstone nodules
*Stratigraphy:* Shale over the 100-foot smut (Waynesburg "A")
*Thickness:* 15 ft
*Elevation of base:* 680 ft
*Type of sample:* Representative channel
*Division of Geological Survey stratigraphic section:* 15357

*Ceramic characteristics*
*Forming method used:* Dry press at 1200 psi
*Tempering water:* 10.6%
*Plasticity and workability:* Satisfactory
*Wet strength:* Satisfactory
*Dry behavior:* Satisfactory
*Linear drying shrinkage:* 0.3%
*Dry strength:* Satisfactory

*Slow-fired properties*

| Temp. (°F) | 24 abs. (%) | 5 abs. (%) | C.A. | L.S. (%) | M.O.R. (psi) | Hard. (Mohs) | Color | Remarks |
|---|---|---|---|---|---|---|---|---|
| 1800 | 14.3 | 16.3 | 0.88 | 1.3 | 390 | 2½ | light orange brown | |
| 1875 | 12.5 | 14.7 | 0.85 | 1.0 | 1530 | 3+ | orange brown | s, sl co |
| 1950 | 9.2 | 11.3 | 0.81 | 2.7 | 1630 | 4- | orange brown | s, sl co |
| 2025 | 7.2 | 9.8 | 0.73 | 3.4 | 2530 | 5 | red brown | w, sl co |
| 2100 | 4.7 | 8.5 | 0.55 | 3.8 | 1540 | 7 | dark red brown | o, b, w |
| 2175 | | | | | | | | |

*Particle-size analysis:* Sand and larger %: ND Silt %: ND Clay %: ND
*pH:* 7.7
*Pyrometric cone equivalent:*
*Other test results:*
*Present and past use:*
*Potential use:* Building brick, drain tile, structural tile
*Remarks:* Very short maturing range

*Sample no.:* 84-0456
*County:* Washington
*Quadrangle (7½'):* Watertown
*Township:* Watertown
*Section or grid coordinates:* x = 2,246,200 ft, y = 539,900 ft
*Site:* Road cut on E side of SR 76, approximately 1 mi N of Watertown
*Lithology:* Clay, gray and maroon, calcareous; sandy in places; limy nodules
*Stratigraphy:* Washington clay
*Thickness:* 19.3 ft
*Elevation of base:* 754 ft
*Type of sample:* Representative channel
*Division of Geological Survey stratigraphic section:* 15357

*Ceramic characteristics*
*Forming method used:* De-aired extrusion
*Tempering water:* 18.9%
*Plasticity and workability:* Plasticity moderately low, extrusion stiff
*Wet strength:* Slightly low but adequate
*Dry behavior:* Slight white scum
*Linear drying shrinkage:* 6.2%
*Dry strength:* 682 psi

*Slow-fired properties*

| Temp. (°F) | 24 abs. (%) | 5 abs. (%) | C.A. | L.S. (%) | M.O.R. (psi) | Hard. (Mohs) | Color | Remarks |
|---|---|---|---|---|---|---|---|---|
| 1800 | 8.4 | 9.5 | .88 | 1.2 | 1220 | 6½ | orange | p, w, co, s |
| 1875 | 7.0 | 8.0 | .88 | 2.2 | 1740 | 7 | orange | p, w, co, s, cr |
| 1950 | 3.8 | 4.6 | .83 | 3.1 | 2740 | 9- | orange brown | p, w, co, s, cr |
| 2025 | 1.1 | 1.4 | .79 | 4.1 | 2220 | 9- | red brown | p, w, co, s, cr, m |
| 2100 | 1.2 | 3.7 | .32 | 2.6 | 3390 | 9- | dark red brown | p, w, co, s, o |
| 2175 | | | | | | | | |

*Particle-size analysis:* Sand and larger %: ND Silt %: ND Clay %: ND
*pH:* 8.1
*Pyrometric cone equivalent:* 5-6, with signs of bloating
*Other test results:*
*Present and past use:*
*Potential use:* Building brick
*Remarks:*

*Sample no.:* 84-0456A
*County:* Washington
*Quadrangle (7½'):* Watertown
*Township:* Watertown
*Section or grid coordinates:* x = 2,246,200 ft, y = 539,900 ft
*Site:* Road cut on E side of SR 76, approximately 1 mi N of Watertown
*Lithology:* Clay, light- to medium-gray, sandy, calcareous
*Stratigraphy:* Washington clay
*Thickness:* 7 ft
*Elevation of base:* 766 ft
*Type of sample:* Representative sample of upper 7 ft of sample 84-0456
*Division of Geological Survey stratigraphic section:* 15357

*Ceramic characteristics*

*Forming method used:* Dry press at 1200 psi
*Tempering water:* 12.0%
*Plasticity and workability:* Plasticity moderately low
*Wet strength:* Satisfactory
*Dry Behavior:* Satisfactory
*Linear drying shrinkage:* 1.9%
*Dry strength:* 44 psi

*Slow-fired properties*

| Temp. (°F) | 24 abs. (%) | 5 abs. (%) | C.A. | L.S. (%) | M.O.R. (psi) | Hard. (Mohs) | Color | Remarks |
|---|---|---|---|---|---|---|---|---|
| 1800 | 11.4 | 12.6 | 0.91 | 1.0 | 1290 | 4 | light orange brown | co |
| 1875 | 8.6 | 9.9 | 0.87 | 3.4 | 1320 | 5½ | orange brown | w, sl co |
| 1950 | 6.1 | 8.2 | 0.74 | 3.4 | 1790 | 7 | dark red brown | cr, w, m |
| 2025 | 5.0 | 7.8 | 0.64 | 1.3 | 1850 | 7 | dark red brown | cr, co, sl b, o |
| 2100 | | | | | | | | |
| 2175 | | | | | | | | |

*Particle-size analysis:* Sand and larger %: ND Silt %: ND Clay %: ND
*pH:* 7.7
*Pyrometric cone equivalent:*
*Other test results:*
*Present and past use:*
*Potential use:* Building brick, face brick
*Remarks:* Low dry strength

*Sample no.;* 84-0456B
*County:* Washington
*Quadrangle (7½'):* Watertown
*Township:* Watertown
*Section or grid coordinates:* x = 2,246,200 ft, y = 539,900 ft
*Site:* Road cut on E side of SR 76, approximately 1 mi N of Watertown
*Lithology:* Clay, gray and lavender, sandy, calcareous
*Stratigraphy:* Washington clay
*Thickness:* 4.3 ft
*Elevation of base:* 762 ft
*Type of sample:* Representative channel of center 4.3 ft of sample 84-0456
*Division of Geological Survey stratigraphic section:* 15357

*Ceramic characteristics*
*Forming method used:* Dry press at 1200 psi
*Tempering water:* 10.5%
*Plasticity and workability:* Plasticity moderately low
*Wet strength:* Satisfactory
*Dry behavior:* Satisfactory
*Linear drying shrinkage:* 1.1%
*Dry strength:* 137 psi

*Slow-fired properties*

| Temp. (°F) | 24 abs. (%) | 5 abs. (%) | C.A. | L.S. (%) | M.O.R. (psi) | Hard. (Mohs) | Color | Remarks |
|---|---|---|---|---|---|---|---|---|
| 1800 | 13.2 | 14.4 | 0.92 | 0.1 | 370 | 4 | light orange tan | |
| 1875 | 10.1 | 11.5 | 0.88 | 1.9 | 1160 | 5 | orange brown | |
| 1950 | 7.8 | 9.1 | 0.86 | 2.9 | 1420 | 5 | red brown | |
| 2025 | 6.4 | 7.9 | 0.81 | 3.9 | 1980 | 6 | red brown | sl cr |
| 2100 | 2.3 | 4.0 | 0.58 | 5.8 | 3580 | 9 | dark red brown | m |
| 2175 | 1.8 | 3.1 | 0.58 | 6.1 | 4330 | 9 | dark red brown | sl o |

*Particle-size analysis:* Sand and larger %: ND Silt %: ND Clay %: ND
*pH:* 8.7
*Pyrometric cone equivalent:*
*Other test results:* Plastic limit 17%
*Present and past use:*
*Potential use:* Building brick, face brick
*Remarks:* Low dry strength

*Sample no.:* 84-0456C
*County:* Washington
*Quadrangle (7½'):* Watertown
*Township:* Watertown
*Section or grid coordinates:* x = 2, 246,200 ft, y = 539,900 ft
*Site:* Road cut on E side of SR 76, approximately 1 mi N of Watertown
*Lithology:* Clay, maroon and green, calcareous
*Stratigraphy:* Washington clay
*Thickness:* 8 ft
*Elevation of base:* 754 ft
*Type of sample:* Representative sample of lower 8 ft of sample 84-0456
*Division of Geological Survey stratigraphic section:* 15357

*Ceramic characteristics*
*Forming method used:* Dry press at 1200 psi
*Tempering water:* 9.7%
*Plasticity and workability:* Plasticity moderately low
*Wet strength:* Satisfactory
*Dry behavior:* Scum
*Linear drying shrinkage:* 1.9%
*Dry strength:* 179 psi

*Slow-fired properties*

| Temp. (°F) | 24 abs. (%) | 5 abs. (%) | C.A. | L.S. (%) | M.O.R. (psi) | Hard. (Mohs) | Color | Remarks |
|---|---|---|---|---|---|---|---|---|
| 1800 | 11.6 | 13.2 | 0.88 | 0.5 | 670 | 4 | orange | |
| 1875 | 11.0 | 12.5 | 0.88 | 1.8 | 670 | 5 | orange brown | |
| 1950 | 5.1 | 6.4 | 0.80 | 4.7 | 2560 | 5½ | orange brown | |
| 2025 | 4.0 | 5.5 | 0.73 | 5.1 | 2350 | 6½ | red brown | |
| 2100 | 1.9 | 3.3 | 0.58 | 6.1 | 3640 | 9 | red brown | p, m |
| 2175 | 1.2 | 2.2 | 0.55 | 5.9 | 3380 | 9 | dark red brown | p, sl o |

*Particle-size analysis:* Sand and larger %: ND Silt %: ND Clay %: ND
*pH:* 8.1
*Pyrometric cone equivalent:*
*Other test results:*
*Present and past use:*
*Potential use:* Building brick
*Remarks:* Long maturing range, low dry strength

*Sample no.:* 84-0457
*County:* Washington
*Quadrangle (7½'):* Fleming
*Township:* Watertown
*Section or grid coordinates:* x = 2,256,200 ft, y = 543,400 ft
*Site:* Road cut on S side of TR 107, approximately 2 mi NE of Watertown
*Lithology:* Clay, yellow-brown, silty
*Stratigraphy:* Minford Silt
*Thickness:* 2.6 ft
*Elevation of base:* 805 ft
*Type of sample:* Representative channel
*Division of Geological Survey stratigraphic section:* NA

*Ceramic characteristics*
*Forming method used:* Dry press at 1200 psi
*Tempering water:* 11.8%
*Plasticity and workability:* Good
*Wet strength:* Satisfactory
*Dry behavior:* Satisfactory
*Linear drying shrinkage:* 0.4%
*Dry strength:* 128 psi

*Slow-fired properties*

| Temp. (°F) | 24 abs. (%) | 5 abs. (%) | C.A. | L.S. (%) | M.O.R. (psi) | Hard. (Mohs) | Color | Remarks |
|---|---|---|---|---|---|---|---|---|
| 1800 | 18.9 | 20.7 | 0.91 | -0.5 | 320 | 2 | orange | |
| 1875 | 18.2 | 20.5 | 0.89 | -0.4 | 340 | 2½ | orange | |
| 1950 | 17.3 | 19.8 | 0.87 | -0.2 | 410 | 2½ | orange | |
| 2025 | 15.9 | 18.4 | 0.86 | 0.6 | 660 | 2½ | orange | |
| 2100 | 12.1 | 14.8 | 0.82 | 2.4 | 1680 | 5½ | orange brown | |
| 2175 | 9.2 | 11.5 | 0.80 | 4.2 | 2310 | 6½ | red brown | almost m |

*Particle-size analysis:* Sand and larger %: 9 Silt %: 63 Clay %: 28
*pH:* 5.5
*Pyrometric cone equivalent:*
*Other test results:* Plastic limit 20%
*Present and past use:*
*Potential use:* Building brick, face brick, structural tile, floor tile, chimney tile, drain tile
*Remarks:* Sample matures above test range

*Sample no.:* 84-0458
*County:* Washington
*Quadrangle (7½'):* Little Hocking
*Township:* Barlow
*Section or grid coordinates:* SW¼ of NE¼ sec. 25
*Site:* Road cut at intersection of TR 53 and TR 24, approximately 1¼ mi SW of Vincent
*Lithology:* Silt, brown, clayey, moderately plastic
*Stratigraphy:* Minford Silt
*Thickness:* 3.4 ft
*Elevation of base:* 747 ft
*Type of sample:* Representative channel
*Division of Geological Survey stratigraphic section:* NA

*Ceramic characteristics*

*Forming method used:* Dry press at 1200 psi
*Tempering water:* 10.8%
*Plasticity and workability:* Plasticity moderate
*Wet strength:* Satisfactory
*Dry behavior:* Satisfactory
*Linear drying shrinkage:* 0.2%
*Dry strength:* 160 psi

*Slow-fired properties*

| Temp. (°F) | 24 abs. (%) | 5 abs. (%) | C.A. | L.S. (%) | M.O.R. (psi) | Hard. (Mohs) | Color | Remarks |
|---|---|---|---|---|---|---|---|---|
| 1800 | 15.9 | 17.9 | 0.89 | -0.8 | 90 | 2½ | light orange tan | |
| 1875 | 15.8 | 18.2 | 0.87 | -0.8 | — | 2½ | light orange tan | |
| 1950 | 15.0 | 17.4 | 0.86 | -0.4 | 110 | 3- | orange tan | |
| 2025 | 14.1 | 16.7 | 0.84 | -0.2 | 334 | 3- | orange brown | |
| 2100 | 12.6 | 15.2 | 0.83 | 0.2 | 445 | 3- | orange brown | |
| 2175 | 10.4 | 13.5 | 0.77 | 1.2 | 664 | 6 | red brown | m |

*Particle-size analysis:* Sand and larger %: 33 Silt %: 41 Clay %: 26
*pH:* 5.2
*Pyrometric cone equivalent:*
*Other test results:* Plastic limit 16%
*Present and past use:*
*Potential use:* Building brick, face brick, floor tile, chimney tile, structural tile
*Remarks:* Very low strength, high porosity

*Sample no.:* 84-0459B
*County:* Washington
*Quadrangle (7½'):* Little Hocking
*Township:* Dunham
*Section or grid coordinates:* NE¼ of NW¼ sec. 24
*Site:* Road cut on SR 76, approximately 1 mi N of Veto
*Lithology:* Silt, yellow-brown, clayey, sandy
*Stratigraphy:* Minford Silt
*Thickness:* 3.5 ft
*Elevation of base:* 740 ft
*Type of sample:* Grab of upper 2 ft
*Division of Geological Survey stratigraphic section:* 15302

*Ceramic characteristics*
*Forming method used:* Dry press at 1200 psi
*Tempering water:* 12.8%
*Plasticity and workability:* Plasticity low
*Wet strength:* Low
*Dry behavior:* Cracking
*Linear drying shrinkage:* 0.9%
*Dry strength:* 174 psi

*Slow-fired properties*

| Temp. (°F) | 24 abs. (%) | 5 abs. (%) | C.A. | L.S. (%) | M.O.R. (psi) | Hard. (Mohs) | Color | Remarks |
|---|---|---|---|---|---|---|---|---|
| 1800 | 16.0 | 17.6 | 0.91 | -0.4 | 20 | 2½ | light orange and tan speckled | |
| 1875 | 16.0 | 17.5 | 0.91 | 0.0 | 0 | 2½ | light orange and tan speckled | |
| 1950 | 14.7 | 16.3 | 0.90 | 0.4 | 200 | 3½ | orange and tan speckled | |
| 2025 | 13.8 | 15.3 | 0.90 | 0.4 | 190 | 4- | orange and tan speckled | |
| 2100 | 13.2 | 15.1 | 0.87 | 0.7 | 700 | 4- | orange and tan speckled | |
| 2175 | 12.2 | 13.9 | 0.88 | 1.3 | 780 | 5+ | red and tan speckled | m |

*Particle-size analysis:* Sand and larger %: 20 Silt %: 50 Clay %: 30
*pH:* 5.2
*Pyrometric cone equivalent:*
*Other test results:*
*Present and past use:*
*Potential use:* Building brick, face brick, decorative brick
*Remarks:* Very low strength, high porosity

*Sample no.:* 84-0460
*County:* Washington
*Quadrangle (7½'):* Rinard Mills
*Township:* Grandview
*Section or grid coordinates:* NW¼ of NE¼ sec. 5
*Site:* Road cut at intersection of CR 9 and TR 427 in Ward
*Lithology:* Mudstone, maroon, very calcareous
*Stratigraphy:* Creston Reds
*Thickness:* 16 ft
*Elevation of base:* 1089 ft
*Type of sample:* Representative channel of lower 14.5 ft
*Division of Geological Survey stratigraphic section:* 12618

*Ceramic characteristics*
*Forming method used:* Dry press at 1200 psi
*Tempering water:* 11.9%
*Plasticity and workability:* Plasticity moderate
*Wet strength:* Satisfactory
*Dry behavior:* Satisfactory
*Linear drying shrinkage:* 2.3%
*Dry strength:* 135 psi

*Slow-fired properties*

| Temp. (°F) | 24 abs. (%) | 5 abs. (%) | C.A. | L.S. (%) | M.O.R. (psi) | Hard. (Mohs) | Color | Remarks |
|---|---|---|---|---|---|---|---|---|
| 1800 | 11.9 | 12.9 | 0.92 | 1.8 | 1150 | 5- | orange brown | sl cr |
| 1875 | 10.0 | 11.3 | 0.89 | 1.5 | 1300 | 5 | orange brown | sl cr |
| 1950 | 9.2 | 10.7 | 0.86 | 2.1 | 1420 | 5 | red brown | sl cr |
| 2025 | 8.4 | 9.9 | 0.85 | 2.5 | 1540 | 5+ | red brown | sl cr |
| 2100 | 4.1 | 6.7 | 0.61 | 1.7 | 1900 | 5½ | red brown | sl cr, m |
| 2175 | 0.7 | 2.3 | 0.30 | 3.0 | 2540 | 9- | dark red brown | sl cr, w, p, m |

*Particle-size analysis:* Sand and larger %: ND Silt: ND Clay %: ND
*pH:* 8.0
*Pyrometric cone equivalent:* 7-8
*Other test results:*
*Present and past use:*
*Potential use:* Building brick, face brick, drain tile, structural tile, sewer pipe
*Remarks:* Relatively long maturing range

*Sample no.:* 84-0461B
*County:* Washington
*Quadrangle (7½'):* Rinard Mills
*Township:* Ludlow
*Section or grid coordinates:* SW¼ of SW¼ sec. 31
*Site:* Road cut on SR 26, approximately 1¼ mi SW of Wingate Run
*Lithology:* Clay, medium-gray to olive-green, moderately plastic; silty at base
*Stratigraphy:* Meigs Creek clay
*Thickness:* 8 ft
*Elevation of base:* 757 ft
*Type of sample:* Representative of upper 6 ft
*Division of Geological Survey stratigraphic section:* 6423

*Ceramic characteristics*
*Forming method used:* Dry press at 1200 psi
*Tempering water:* 11.4%
*Plasticity and workability:* Plasticity moderate
*Wet strength:* Satisfactory
*Dry behavior:* Satisfactory
*Linear drying shrinkage:* 1.5%
*Dry strength:* 197 psi

*Slow-fired properties*

| Temp. (°F) | 24 abs. (%) | 5 abs. (%) | C.A. | L.S. (%) | M.O.R. (psi) | Hard. (Mohs) | Color | Remarks |
|---|---|---|---|---|---|---|---|---|
| 1800 | 16.9 | 18.2 | 0.93 | 0.5 | 510 | 3- | light orange | |
| 1875 | 13.0 | 14.4 | 0.90 | 1.8 | 1280 | 4- | orange | |
| 1950 | 9.7 | 11.1 | 0.87 | 5.0 | 1440 | 5½ | orange | sl w, sl s |
| 2025 | 5.6 | 7.0 | 0.80 | 6.4 | 2620 | 7 | orange brown | sl w, sl s |
| 2100 | 1.8 | 3.2 | 0.56 | 7.8 | 3780 | 7 | red brown | w, m |
| 2175 | 1.7 | 8.3 | 0.20 | 5.0 | 3590 | 9- | red brown | w, b, co, o |

*Particle-size analysis:* Sand and larger %: 29 Silt %: 50 Clay %: 21
*pH:* 3.4
*Pyrometric cone equivalent:* 14-15, with signs of bloating
*Other test results:*
*Present and past use:*
*Potential use:* Building brick, face brick, structural tile, drain tile, sewer pipe, conduit
*Remarks:* Low dry strength

*Sample no.:* 84-0463
*County:* Washington
*Quadrangle (7½'):* Dalzell
*Township:* Liberty
*Section or grid coordinates:* SW¼ of SW¼ sec. 28
*Site:* Road cut on CR 371, approximately 1¾ mi W of Dalzell
*Lithology:* Clay, light-gray to olive-green, sandy, iron-stained
*Stratigraphy:* Meigs Creek clay
*Thickness:* 4.8 ft
*Elevation of base:* 725 ft
*Type of sample:* Representative channel
*Division of Geological Survey stratigraphic section:* 2836

*Ceramic characteristics*
*Forming method used:* De-aired extrusion
*Tempering water:* 29.3
*Plasticity and workability:* Plasticity high, extrusion very good
*Wet strength:* Satisfactory
*Dry behavior:* Trace of scum and lamination cracks
*Linear drying shrinkage:* 7.7%
*Dry strength:* 537 psi

*Slow-fired properties*

| Temp. (°F) | 24 abs. (%) | 5 abs. (%) | C.A. | L.S. (%) | M.O.R. (psi) | Hard. (Mohs) | Color | Remarks |
|---|---|---|---|---|---|---|---|---|
| 1800 | 14.2 | 15.2 | 0.93 | 0.9 | 3180 | 5 | light orange | sl s |
| 1875 | 11.8 | 13.0 | 0.91 | 1.8 | 3600 | 5½ | light orange | sl s |
| 1950 | 6.7 | 7.3 | 0.92 | 4.2 | 4390 | 7½ | orange | sl s |
| 2025 | 2.3 | 2.8 | 0.82 | 6.3 | 6260 | 8 | orange brown | sl s |
| 2100 | 0.6 | 0.8 | 0.75 | 7.4 | 7430 | 9- | red brown | sl s, sl w, m |
| 2175 | 0.6 | 3.8 | 0.16 | 7.3 | 4210 | 9 | dark red brown | sl w, co, o |

*Particle-size analysis:* Sand and larger %: 37 Silt %: 41 Clay %: 22
*pH:* 5.5
*Pyrometric cone equivalent:*
*Other test results:*
*Present and past use:*
*Potential use:* Building brick, face brick, structural tile, wall tile, roofing tile, artware, chimney tile, conduit, sewer pipe
*Remarks:* Very high strength, very low absorption, high shrinkage

*Sample no.:* 84-0466
*County:* Washington
*Quadrangle (7½'):* Lower Salem
*Township:* Aurelius
*Section or grid coordinates:* SE¼ of SW¼ sec. 28
*Site:* Coal strip mine, approximately 1½ mi SW of Elba
*Lithology:* Clay, light- to medium-gray, iron-stained; ironstone nodules
*Stratigraphy:* Meigs Creek clay
*Thickness:* 9 ft
*Elevation of base:* 841 ft
*Type of sample:* Representative channel
*Division of Geological Survey stratigraphic section:* 15276

*Ceramic characteristics*
*Forming method used:* Dry press at 1200 psi
*Tempering water:* 14.0%
*Plasticity and workability:* Plasticity moderately high
*Wet strength:* Satisfactory
*Dry behavior:* Satisfactory
*Linear drying shrinkage:* 1.1%
*Dry strength:* 179 psi

*Slow-fired properties*

| Temp. (°F) | 24 abs. (%) | 5 abs. (%) | C.A. | L.S. (%) | M.O.R. (psi) | Hard. (Mohs) | Color | Remarks |
|---|---|---|---|---|---|---|---|---|
| 1800 | 19.3 | 20.9 | 0.92 | 0.7 | 490 | 3 | light red brown | |
| 1875 | 15.8 | 17.8 | 0.89 | 2.9 | 900 | 4 | light red brown | |
| 1950 | 8.3 | 10.5 | 0.79 | 7.1 | 2150 | 5½ | red brown | |
| 2025 | 6.8 | 8.6 | 0.79 | 7.4 | 2120 | 6+ | red brown | very sl w |
| 2100 | 3.5 | 5.1 | 0.69 | 8.6 | 2940 | 9 | dark red brown | very sl w, b, m |
| 2175 | 1.8 | 3.8 | 0.47 | 8.9 | 3550 | 9 | dark red brown | very sl w, b, p, m |

*Particle-size analysis:* Sand and larger %: ND Silt %: ND Clay %: ND
*pH:* 3.5
*Pyrometric cone equivalent:* 11-12, with signs of bloating
*Other test results:*
*Present and past use:*
*Potential use:* Building brick, sewer pipe, conduit
*Remarks:* Relatively long maturing range

*Sample no.:* 84-0467
*County:* Washington
*Quadrangle (7½'):* Lower Salem
*Township:* Aurelius
*Section or grid coordinates:* NE¼ of SW¼ sec. 28
*Site:* Coal strip mine, approximately 1½ mi SW of Elba
*Lithology:* Shale and clay, gray and olive-green; sandy at top
*Stratigraphy:* Shale below Meigs Creek clay
*Thickness:* 10 ft
*Elevation of base:* 823 ft
*Type of sample:* Representative channel
*Division of Geological Survey stratigraphic section:* 15276

*Ceramic characteristics*
*Forming method used:* Dry press at 1200 psi
*Tempering water:* 15.5%
*Plasticity and workability:* Satisfactory
*Wet strength:* Satisfactory
*Dry behavior:* Satisfactory
*Linear drying shrinkage:* 1.2%
*Dry strength:* 189 psi

*Slow-fired properties*

| Temp. (°F) | 24 abs. (%) | 5 abs. (%) | C.A. | L.S. (%) | M.O.R. (psi) | Hard. (Mohs) | Color | Remarks |
|---|---|---|---|---|---|---|---|---|
| 1800 | 14.9 | 16.0 | 0.93 | 2.4 | 1080 | 2 | light orange tan | sl w |
| 1875 | 13.2 | 14.7 | 0.90 | 2.7 | 1230 | 2+ | light orange tan | sl w |
| 1950 | 9.9 | 11.4 | 0.87 | 3.6 | 1680 | 3 | orange | sl w |
| 2025 | 5.2 | 6.4 | 0.81 | 5.8 | 2630 | 5½ | orange brown | sl w, m |
| 2100 | 3.8 | 4.9 | 0.78 | 7.7 | 2740 | 6 | red brown | sl w, m |
| 2175 | 2.9 | 3.8 | 0.76 | 7.6 | 3760 | 7 | red brown | sl w, m |

*Particle-size analysis:* Sand and larger %: ND Silt %: ND Clay %: ND
*pH:* 4.4
*Pyrometric cone equivalent:*
*Other test results:*
*Present and past use:*
*Potential use:* Building brick, face brick, drain tile, structural tile, sewer pipe
*Remarks:* Relatively long maturing range

*Sample no.:* 84-0468
*County:* Washington
*Quadrangle (7½'):* Watertown
*Township:* Palmer
*Section or grid coordinates:* x = 2,224,700 ft, y = 531,400 ft
*Site:* Road cut on N side of SR 676, approximately 1 mi SE of Browns Mill
*Lithology:* Clay, yellow-brown, silty, nonbedded
*Stratigraphy:* Minford Silt
*Thickness:* 4.5 ft
*Elevation of base:* 801 ft
*Type of sample:* Representative channel
*Division of Geological Survey stratigraphic section:* NA

*Ceramic characteristics*
*Forming method used:* Dry press at 1200 psi (see note fig. 36, p. 74)
*Tempering water:* 14.5%
*Plasticity and workability:* Plasticity high
*Wet strength:* Satisfactory
*Dry behavior:* Satisfactory
*Linear drying shrinkage:* 1.1%
*Dry strength:* 210 psi

*Slow-fired properties*

| Temp. (°F) | 24 abs. (%) | 5 abs. (%) | C.A. | L.S. (%) | M.O.R. (psi) | Hard. (Mohs) | Color | Remarks |
|---|---|---|---|---|---|---|---|---|
| 1800 | 17.4 | 19.2 | 0.91 | -0.5 | 240 | 2½ | orange | |
| 1875 | 16.4 | 18.5 | 0.89 | 0.1 | 380 | 2½ | orange brown | |
| 1950 | 15.6 | 17.3 | 0.90 | 1.1 | 650 | 3½ | orange brown | |
| 2025 | 11.6 | 14.0 | 0.83 | 2.4 | 1100 | 4½ | orange brown | |
| 2100 | 7.0 | 9.0 | 0.78 | 5.0 | 2700 | 7- | red brown | sl w |
| 2175 | 5.4 | 7.8 | 0.69 | 5.9 | 3080 | 9- | red brown | sl w, m |

*Particle-size analysis:* Sand and larger %: 8 Silt %: 56 Clay %: 36
*pH:* 5.6
*Pyrometric cone equivalent:* 14
*Other test results:*
*Present and past use:*
*Potential use:* Building brick, face brick, drain tile, structural tile, sewer pipe, artware
*Remarks:* Not fired to optimum temperature

*Sample no.:* 84-0468
*County:* Washington
*Quadrangle (7½'):* Watertown
*Township:* Palmer
*Section or grid coordinates:* x = 2,224,700 ft, y = 531,400 ft
*Site:* Road cut on N side of SR 676, approximately 1 mi SE of Browns Mill
*Lithology:* Clay, yellow-brown, silty, nonbedded
*Stratigraphy:* Minford Silt
*Thickness:* 4.5 ft
*Elevation of base:* 801 ft
*Type of sample:* Representative channel
*Division of Geological Survey stratigraphic section:* NA

*Ceramic characteristics*
*Forming method used:* De-aired extrustion
*Tempering water:* 24.2%
*Plasticity and workability:* Plasticity high, extrusion good
*Wet strength:* Satisfactory
*Dry behavior:* Satisfactory
*Linear drying shrinkage:* 8.2%
*Dry strength:* 545 psi

*Slow-fired properties*

| Temp. (°F) | 24 abs. (%) | 5 abs. (%) | C.A. | L.S. (%) | M.O.R. (psi) | Hard. (Mohs) | Color | Remarks |
|---|---|---|---|---|---|---|---|---|
| 1800 | 14.8 | 16.0 | 0.93 | 0.5 | 580 | 2½ | orange | very sl w |
| 1875 | 13.3 | 14.8 | 0.90 | 0.9 | 980 | 2½ | orange brown | very sl w |
| 1950 | 11.7 | 14.3 | 0.82 | 2.1 | 1620 | 5½ | orange brown | very sl w |
| 2025 | 8.9 | 11.2 | 0.80 | 3.4 | 1590 | 5½ | orange brown | very sl w |
| 2100 | 5.0 | 7.3 | 0.69 | 5.3 | 6680 | 7 | red brown | very sl w |
| 2175 | 2.8 | 3.0 | 0.93 | 6.0 | 5510 | 9 | red brown | very sl w, m |

*Particle-size analysis:* Sand and larger %: 8 Silt %: 56 Clay %: 36
*pH:* 5.6
*Pyrometric cone equivalent:* 14
*Other test results:*
*Present and past use:*
*Potential use:* Building brick, face brick, structural tile, sewer pipe, drain tile, artware
*Remarks:* Drying shrinkage very high

*Sample no.:* 84-0469
*County:* Washington
*Quadrangle (7½'):* Chesterhill
*Township:* Wesley
*Section or grid coordinates:* NW¼ of NE¼ sec. 30
*Site:* Road cut in W side CR 206, approximately 1 mi S of Patten Mills
*Lithology:* Shale, light-gray to olive-green to red and green, fissile, silty
*Stratigraphy:* Uniontown shale
*Thickness:* 10 ft
*Elevation of base:* 778 ft
*Type of sample:* Representative channel
*Division of Geological Survey stratigraphic section:* 3179R

*Ceramic characteristics*
*Forming method used:* Dry press at 1200 psi
*Tempering water:* 11.5%
*Plasticity and workability:* Satisfactory
*Wet strength:* Satisfactory
*Dry behavior:* Satisfactory
*Linear drying shrinkage:* 1.1%
*Dry strength:* 196 psi

*Slow-fired properties*

| Temp. (°F) | 24 abs. (%) | 5 abs. (%) | C.A. | L.S. (%) | M.O.R. (psi) | Hard. (Mohs) | Color | Remarks |
|---|---|---|---|---|---|---|---|---|
| 1800 | 9.7 | 11.2 | 0.87 | 2.1 | 2290 | 4 | orange tan | sl co |
| 1875 | 7.9 | 9.5 | 0.83 | 2.8 | 2400 | 5- | orange tan | sl co |
| 1950 | 5.8 | 7.4 | 0.78 | 4.0 | 2500 | 5½ | orange brown | sl co |
| 2025 | 3.7 | 5.5 | 0.67 | 4.2 | | 7 | red brown | co, m |
| 2100 | 2.5 | 4.7 | 0.53 | 4.5 | | 7 | red brown | co, b, cr, m |
| 2175 | 1.3 | 5.4 | 0.24 | 2.5 | 3420 | 8½ | red brown | b, p, w, o |

*Particle-size analysis:* Sand and larger %: ND Silt %: ND Clay %: ND
*pH:* 7.2
*Pyrometric cone equivalent:*
*Other test results:*
*Present and past use:*
*Potential use:* Building brick, drain tile, structural tile, sewer pipe
*Remarks:* No data available for 2025° M.O.R. and 2100° M.O.R. because of test machine malfunction

*Sample no.:* 84-0470
*County:* Washington
*Quadrangle (7½'):* Marietta
*Township:* Marietta
*Section or grid coordinates:* NE¼ sec. 34
*Site:* Road cut at junction of SR 7 and US 50A near W edge of Marietta
*Lithology:* Clay, gray to olive-green, calcareous; limestone nodules
*Stratigraphy:* Washington clay
*Thickness:* 7 ft
*Elevation of base:* 650 ft
*Type of sample:* Representative channel
*Division of Geological Survey stratigraphic section:* 15072

*Ceramic characteristics*
*Forming method used:* Dry press at 1200 psi
*Tempering water:* 11.3%
*Plasticity and workability:* Plasticity moderate
*Wet strength:* Satisfactory
*Dry behavior:* Satisfactory
*Linear drying shrinkage:* 1.3%
*Dry strength:* 130 psi

*Slow-fired properties*

| Temp. (°F) | 24 abs. (%) | 5 abs. (%) | C.A. | L.S. (%) | M.O.R. (psi) | Hard. (Mohs) | Color | Remarks |
|---|---|---|---|---|---|---|---|---|
| 1800 | 12.9 | 14.5 | 0.89 | 0.3 | 560 | 4- | orange brown | very sl cr |
| 1875 | 12.9 | 15.2 | 0.85 | 0.4 | 550 | 4 | orange brown | very sl cr |
| 1950 | 12.4 | 14.5 | 0.86 | 0.4 | 780 | 5- | orange brown | very sl cr |
| 2025 | 10.9 | 13.2 | 0.83 | 0.5 | 1100 | 5 | orange brown | very sl cr, u |
| 2100 | 4.1 | 8.9 | 0.46 | 2.1 | 2810 | 8 | dark red brown | p, sl o |
| 2175 | 0.4 | 1.9 | 0.21 | 0.4 | 3040 | 9 | dark red brown | w, o |

*Particle-size analysis:* Sand and larger %: ND Silt %: ND Clay %: ND
*pH:* 8.6
*Pyrometric cone equivalent:*
*Other test results:*
*Present and past use:*
*Potential use:* Building brick
*Remarks:*

*Sample no.:* 84-0471
*County:* Washington
*Quadrangle (7½'):* Little Hocking
*Township:* Belpre
*Section or grid coordinates:* NW¼ of NW¼ sec. 15
*Site:* Road cut on township road at Corner
*Lithology:* Clay, brown, very calcareous; limestone nodules
*Stratigraphy:* Washington clay
*Thickness:* 13.0 ft
*Elevation of base:* 634 ft
*Type of sample:* Representative channel
*Division of Geological Survey stratigraphic section:* 15227

*Ceramic characteristics*

*Forming method used:* Dry press at 1200 psi
*Tempering water:* 13.0%
*Plasticity and workability:* Plasticity moderately high
*Wet strength:* Satisfactory
*Dry behavior:* Satisfactory
*Linear drying shrinkage:* 2.2%
*Dry strength:* 143 psi

*Slow-fired properties*

| Temp. (°F) | 24 abs. (%) | 5 abs. (%) | C.A. | L.S. (%) | M.O.R. (psi) | Hard. (Mohs) | Color | Remarks |
|---|---|---|---|---|---|---|---|---|
| 1800 | 13.4 | 14.9 | 0.90 | 1.7 | 750 | 4 | orange brown | sl p |
| 1875 | 13.3 | 14.4 | 0.92 | 2.1 | 1080 | 5 | orange brown | sl p |
| 1950 | 11.0 | 12.9 | 0.85 | 3.0 | 1080 | 5½ | orange brown | sl p |
| 2025 | 9.4 | 11.5 | 0.82 | 3.3 | 1500 | 7 | red brown | sl p, m |
| 2100 | 3.7 | 6.8 | 0.54 | 4.0 | 1660 | 7+ | red brown | sl p, m |
| 2175 | 4.5 | 8.0 | 0.56 | 4.1 | 2030 | 9+ | dark red brown | sl p, sl o |

*Particle-size analysis:* Sand and larger %: ND Silt %: ND Clay %: ND
*pH:* 8.6
*Pyrometric cone equivalent:* 7
*Other test results:* Plastic limit 22%
*Present and past use:*
*Potential use:* Building brick
*Remarks:* Strength could probably be improved by increasing the forming pressure or by extrusion

*Sample no.:* 84-0472
*County:* Washington
*Quadrangle (7½'):* Little Hocking
*Township:* Belpre
*Section or grid coordinates:* NE¼ of NE¼ sec. 21
*Site:* Road cut on SR 76 at Corner
*Lithology:* Mudstone, pale-grayish-red and olive-green, very calcareous, silty; limy nodules
*Stratigraphy:* Creston Reds
*Thickness:* 25 ft (base not exposed)
*Elevation of base:* 701 ft
*Type of sample:* Representative sample of upper 25 ft
*Division of Geological Survey stratigraphic section:* 15227

*Ceramic characteristics*

*Forming method used:* Dry press at 1200 psi (see note fig. 36, p. 74)
*Tempering water:* 11.2%
*Plasticity and workability:* Plasticity moderate
*Wet strength:* Slightly low, but adequate
*Dry behavior:* Satisfactory
*Linear drying shrinkage:* 1.5%
*Dry strength:* 125 psi

*Slow-fired properties*

| Temp. (°F) | 24 abs. (%) | 5 abs. (%) | C.A. | L.S. (%) | M.O.R. (psi) | Hard. (Mohs) | Color | Remarks |
|---|---|---|---|---|---|---|---|---|
| 1800 | 13.4 | 14.7 | 0.91 | 1.4 | 830 | 4½ | orange brown | sl p |
| 1875 | 13.2 | 14.9 | 0.89 | 1.5 | 910 | 5 | orange brown | sl p |
| 1950 | 11.2 | 13.3 | 0.84 | 1.6 | 1012 | 5+ | orange brown | sl p |
| 2025 | 8.6 | 11.0 | 0.78 | 2.3 | 1620 | 7- | red brown | sl p, m |
| 2100 | 2.9 | 5.7 | 0.51 | 3.2 | 2550 | 9- | red brown | sl p, m |
| 2175 | 1.1 | 3.0 | 0.37 | 5.1 | 3200 | 9- | dark red brown | sl p, sl cr, o |

*Particle-size analysis:* Sand and larger %: ND Silt %: ND Clay %: ND
*pH:* 8.4
*Pyrometric cone equivalent:*
*Other test results:*
*Present and past use:*
*Potential use:* Building brick
*Remarks:*

*Sample no.:* 84-0472
*County:* Washington
*Quadrangle (7½'):* Little Hocking
*Township:* Belpre
*Section or grid coordinates:* NE¼ of NE¼ sec. 21
*Site:* Road cut on SR 76 at Corner
*Lithology:* Mudstone, pale-grayish-red and olive-green, very calcareous, silty; limy nodules
*Stratigraphy:* Creston Reds
*Thickness:* 25 ft (base not exposed)
*Elevation of base:* 701 ft
*Type of sample:* Representative channel of upper 25 ft
*Division of Geological Survey stratigraphic section:* 15227

*Ceramic characteristics*
*Forming method used:* De-aired extrusion
*Tempering water:* 20.7%
*Plasticity and workability:* Extrusion stiff
*Wet strength:* Slightly low
*Dry behavior:* Satisfactory
*Linear drying shrinkage:* 5.5%
*Dry strength:* 551 psi

*Slow-fired properties*

| Temp. (°F) | 24 abs. (%) | 5 abs. (%) | C.A. | L.S. (%) | M.O.R. (psi) | Hard. (Mohs) | Color | Remarks |
|---|---|---|---|---|---|---|---|---|
| 1800 | 8.7 | 9.2 | 0.95 | 2.0 | 910 | 6 | orange brown | p, cr, w |
| 1875 | 6.9 | 8.1 | 0.85 | 2.1 | 920 | 7 | orange borwn | p, cr, w |
| 1950 | 6.4 | 7.3 | 0.88 | 2.5 | 1540 | 9- | orange brown | p, cr, w, m |
| 2025 | 2.6 | 3.5 | 0.74 | 3.1 | 1660 | 9 | red brown | p, cr, w, m |
| 2100 | 0.9 | 1.1 | 0.82 | 3.0 | 2140 | 9 | dark red brown | p, cr, w, m |
| 2175 | | | | | | | | |

*Particle-size analysis:* Sand and larger %: ND Silt %: ND Clay %: ND
*pH:* 8.4
*Pyrometric cone equivalent:*
*Other test results:*
*Present and past use:*
*Potential use:* Building brick
*Remarks:* Moderately low strength

*Sample no.:* 84-0473
*County:* Washington
*Quadrangle (7½'):* Marietta
*Township:* Marietta
*Section or grid coordinates:* Center sec. 34
*Site:* Road cut on US 7, approximately ⅜ mi SW of junction with US 50A
*Lithology:* Mudstone, pale-grayish-red; calcareous sandstone stringers
*Stratigraphy:* Creston Reds
*Thickness:* 70 ft
*Elevation of base:* 630 ft
*Type of sample:* Representative channel
*Division of Geological Survey stratigraphic section:* NA

*Ceramic characteristics*
*Forming method used:* Dry press at 1200 psi
*Tempering water:* 12.4%
*Plasticity and workability:* Plasticity moderate
*Wet strength:* Satisfactory
*Dry behavior:* Satisfactory
*Linear drying shrinkage:* 1.9%
*Dry strength:* Satisfactory

*Slow-fired properties*

| Temp. (°F) | 24 abs. (%) | 5 abs. (%) | C.A. | L.S. (%) | M.O.R. (psi) | Hard. (Mohs) | Color | Remarks |
|---|---|---|---|---|---|---|---|---|
| 1800 | 11.7 | 13.4 | 0.87 | 0.1 | 400 | 4- | orange brown | |
| 1875 | 10.4 | 12.2 | 0.85 | 0.8 | 810 | 4 | orange brown | |
| 1950 | 7.7 | 9.6 | 0.80 | 1.5 | 1390 | 5½ | orange brown | |
| 2025 | 6.1 | 8.4 | 0.73 | 1.8 | 2030 | 6- | orange brown | sl u |
| 2100 | 3.5 | 5.5 | 0.64 | 2.8 | 3020 | 9- | red brown | m |
| 2175 | 1.1 | 2.2 | 0.50 | 2.2 | 3610 | 9- | dark red brown | sl o |

*Particle-size analysis:* Sand and larger %: ND Silt %: ND Clay %: ND
*pH:* 8.8
*Pyrometric cone equivalent:* 10
*Other test results:* Plastic limit 16%
*Present and past use:*
*Potential use:* Building brick, face brick, structural tile, drain tile, sewer pipe
*Remarks:* Fairly good firing range and low shrinkage

*Sample no.:* 84-0475
*County:* Washington
*Quadrangle (7½'):* Cutler
*Township:* Decatur
*Section or grid coordinates:* SW½ of SW¼ sec. 10
*Site:* Road cut on SR 555, approximately 1 mi S of Decaturville
*Lithology:* Clay, olive-green, silty, sandy
*Stratigraphy:* Clay below 50-foot smut (Waynesburg)
*Thickness:* 6-10 ft
*Elevation of base:* 657 ft
*Type of sample:* Representative channel
*Division of Geological Survey stratigraphic section:* 15291

*Ceramic characteristics*
*Forming method used:* Dry press at 1200 psi
*Tempering water:* 13.2%
*Plasticity and workability:* Plasticity moderately low
*Wet strength:* Satisfactory
*Dry behavior:* Satisfactory
*Linear drying shrinkage:* 0.8%
*Dry strength:* 145 psi

*Slow-fired properties*

| Temp. (°F) | 24 abs. (%) | 5 abs. (%) | C.A. | L.S. (%) | M.O.R. (psi) | Hard. (Mohs) | Color | Remarks |
|---|---|---|---|---|---|---|---|---|
| 1800 | 11.3 | 13.1 | 0.86 | 2.3 | 1220 | 3 | orange | very sl s very sl w |
| 1875 | 9.9 | 11.7 | 0.85 | 3.3 | 1510 | 4 | orange brown | very sl s very sl w |
| 1950 | 6.8 | 8.5 | 0.80 | 4.2 | 2210 | 5- | orange brown | very sl s very sl w |
| 2025 | 4.4 | 6.0 | 0.73 | 6.0 | 2880 | 6 | orange brown | very sl s very sl w |
| 2100 | 1.7 | 3.1 | 0.55 | 7.1 | 4230 | 7 | red brown | very sl w m |
| 2175 | 1.3 | 3.7 | 0.35 | 3.7 | 3640 | 9 | red brown | w o |

*Particle-size analysis:* Sand and larger %: ND Silt %: ND Clay %: ND
*pH:* 6.7
*Pyrometric cone equivalent:*
*Other test results:*
*Present and past use:*
*Potential use:* Building brick, face brick, structural tile, drain tile, sewer pipe
*Remarks:* Low dry strength, fairly good firing range

*Sample no.:* 84-0551
*County:* Washington
*Quadrangle (7½'):* Parkersburg
*Township:* Belpre
*Section or grid coordinates:* SW¼ of NE¼ sec. 1
*Site:* Blen Haven Corp. sand pit at Belpre
*Lithology:* Silt, gray to brown, clayey, sandy, slightly calcareous
*Stratigraphy:* Recent alluvium
*Thickness:* 15.3 ft
*Elevation of base:* 580 ft
*Type of sample:* Representative channel
*Division of Geological Survey stratigraphic section:* NA

*Ceramic characteristics*
*Forming method used:* Dry press at 1200 psi
*Tempering water:* 12.8%
*Plasticity and workability:* Plasticity moderately low
*Wet strength:* Satisfactory
*Dry behavior:* Satisfactory
*Linear drying shrinkage:* 0.3%
*Dry strength:* 152 psi

*Slow-fired properties*

| Temp. (°F) | 24 abs. (%) | 5 abs. (%) | C.A. | L.S. (%) | M.O.R. (psi) | Hard. (Mohs) | Color | Remarks |
|---|---|---|---|---|---|---|---|---|
| 1800 | 18.5 | 20.4 | 0.91 | -0.6 | 440 | 2½ | orange | |
| 1875 | 18.0 | 19.8 | 0.91 | 0.0 | 540 | 2½ | orange | |
| 1950 | 16.5 | 18.4 | 0.90 | 0.3 | 570 | 2½ | orange | |
| 2025 | 14.9 | 16.8 | 0.89 | 2.0 | 1060 | 4 | orange brown | |
| 2100 | 9.0 | 11.5 | 0.78 | 4.5 | 2210 | 5½ | red brown | |
| 2175 | 4.6 | 6.8 | 0.68 | 6.9 | 2940 | 8+ | dark red brown | m |

*Particle-size analysis:* Sand and larger %: 16 Silt %: 66 Clay %: 18
*pH:* 4.9
*Pyrometric cone equivalent:*
*Other test results:*
*Present and past use:*
*Potential use:* Building brick, face brick, drain tile, structural tile
*Remarks:* Low dry strength, relatively high absorption and shrinkage

*Sample no.:* 84-0580
*County:* Washington
*Quadrangle (7½'):* Watertown
*Township:* Barlow
*Section or grid coordinates:* SW¼ of NE¼ sec. 22
*Site:* Road cut on E side of SR 76, approximately 1 mi N of Barlow
*Lithology:* Clay, reddish-brown, plastic, highly laminated
*Stratigraphy:* Minford Silt
*Thickness:* 5 ft (base not exposed)
*Elevation of base:* 760 ft
*Type of sample:* Grab
*Division of Geological Survey stratigraphic section:* NA

*Ceramic characteristics*
*Forming method used:* Dry press at 1200 psi
*Tempering water:* 20.9%
*Plasticity and workability:* Plasticity very high
*Wet strength:* Satisfactory
*Dry behavior:* Slight cracking, moderate warping, considerable scum
*Linear drying shrinkage:* 3.5%
*Dry strength:* Satisfactory

*Slow-fired properties*

| Temp. (°F) | 24 abs. (%) | 5 abs. (%) | C.A. | L.S. (%) | M.O.R. (psi) | Hard. (Mohs) | Color | Remarks |
|---|---|---|---|---|---|---|---|---|
| 1800 | 16.7 | 17.9 | 0.93 | 0.5 | 1270 | 4¼ | light orange brown | s |
| 1875 | 15.1 | 16.2 | 0.93 | 1.7 | 1290 | 5+ | light orange brown | s |
| 1950 | 9.6 | 11.3 | 0.85 | 5.0 | 1790 | 5½ | orange brown | s, w |
| 2025 | 5.9 | 7.6 | 0.78 | 7.2 | 1960 | 7- | red brown | s, w |
| 2100 | 0.4 | 1.0 | 0.4 | 9.7 | 2240 | 8½ | dark red brown | w, m |
| 2175 | 0.3 | 1.0 | 0.3 | 7.4 | 2340 | 8½ | dark red brown | w, b, o |

*Particle-size analysis:* Sand and larger %: 0 Silt %: 21 Clay %: 79
*pH:* 8.4
*Pyrometric cone equivalent:*
*Other test results:* Plastic limit 28%, liquid limit 49%
*Present and past use:*
*Potential use:* Lightweight aggregate, modeling clay, bonding clay, artware
*Remarks:* Very high plasticity

*Sample no.:* 84-0600B
*County:* Washington
*Quadrangle (7½'):* Lowell
*Township:* Waterford
*Section or grid coordinates:* x = 2,251,200 ft, y = 575,900 ft
*Site:* Road cut on SR 339, approximately 1½ mi NW of Coal Run
*Lithology:* Silt, brown and light-gray, clayey, nonbedded
*Stratigraphy:* Minford Silt
*Thickness:* 4 ft
*Elevation of base:* 920 ft
*Type of sample:* Representative channel
*Division of Geological Survey stratigraphic section:* NA

*Ceramic characteristics*
*Forming method used:* Dry press at 1200 psi
*Tempering water:* 10.3%
*Plasticity and workability:* Plasticity moderate, workability good
*Wet strength:* Satisfactory
*Dry behavior:* Satisfactory
*Linear drying shrinkage:* 0.6%
*Dry strength:* 187 psi

*Slow-fired properties*

| Temp. (°F) | 24 abs. (%) | 5 abs. (%) | C.A. | L.S. (%) | M.O.R. (psi) | Hard. (Mohs) | Color | Remarks |
|---|---|---|---|---|---|---|---|---|
| 1800 | 18.3 | 20.3 | 0.90 | -0.6 | 380 | 2½ | light orange brown | |
| 1875 | 17.7 | 20.3 | 0.87 | -0.6 | 360 | 2½ | light orange brown | |
| 1950 | 16.8 | 18.8 | 0.89 | -0.4 | 360 | 2½ | light orange brown | |
| 2025 | 15.8 | 18.0 | 0.88 | -0.3 | 560 | 3- | light orange brown | |
| 2100 | 14.2 | 16.7 | 0.85 | 1.0 | 1000 | 3½ | orange brown | |
| 2175 | 12.7 | 14.8 | 0.86 | 1.6 | 1280 | 5 | red brown | sl u |

*Particle-size analysis:* Sand and larger %: 14 Silt %: 56 Clay %: 30
*pH:* 5.5
*Pyrometric cone equivalent:*
*Other test results:* Plastic limit 18%
*Present and past use:*
*Potential use:* Building brick, face brick, structural tile
*Remarks:* Low fired and dry strength, high absorption

*Sample no.:* 84-0602
*County:* Washington
*Quadrangle (7½'):* Belmont
*Township:* Newport
*Section or grid coordinates:* SW¼ of SW¼ sec. 35
*Site:* Road cut on CR 9, approximately ½ mi S of Dell
*Lithology:* Silt, brown, clayey; calcareous pebbles in lower 8 ft
*Stratigraphy:* Pleistocene lake silt
*Thickness:* 25 ft (base not exposed)
*Elevation of base:* 620 ft
*Type of sample:* Composite of 5 grabs at 5 ft vertical intervals
*Division of Geological Survey stratigraphic section:* NA

*Ceramic characteristics*
*Forming method used:* Dry press at 1200 psi
*Tempering water:* 13.1%
*Plasticity and workability:* Good
*Wet strength:* Satisfactory
*Dry behavior:* Satisfactory
*Linear drying shrinkage:* 0.5%
*Dry strength:* 179 psi

*Slow-fired properties*

| Temp. (°F) | 24 abs. (%) | 5 abs. (%) | C.A. | L.S. (%) | M.O.R. (psi) | Hard. (Mohs) | Color | Remarks |
|---|---|---|---|---|---|---|---|---|
| 1800 | 19.2 | 20.4 | 0.94 | 0.6 | 1290 | 2½ | light orange brown | |
| 1875 | 16.4 | 17.6 | 0.93 | 1.7 | 1420 | 2½ | orange brown | |
| 1950 | 12.6 | 14.0 | 0.90 | 3.4 | 2010 | 4½ | orange brown | sl s |
| 2025 | 8.4 | 9.8 | 0.86 | 6.8 | 3680 | 7- | red brown | |
| 2100 | 0.5 | 0.6 | 0.83 | 10.5 | 6130 | 9 | dark red brown | m |
| 2175 | 0.1 | 0.3 | 0.33 | 7.6 | 5110 | 9 | dark red brown | b, sl w, o |

*Particle-size analysis:* Sand and larger %: 1 Silt %: 58 Clay %: 41
*pH:* 8.7
*Pyrometric cone equivalent:*
*Other test results:* Plastic limit 25%
*Present and past use:*
*Potential use:* Building brick, face brick, hollow tile, wall tile, sewer pipe, artware
*Remarks:* High fired strength, low dry strength

*Sample no.:* 84-0624
*County:* Washington
*Quadrangle (7½'):* Beverly
*Township:* Waterford
*Section or grid coordinates:* x = 2,239,600 ft, y = 560,200 ft
*Site:* Wolf Creek High School athletic grounds at Waterford
*Lithology:* Silt, medium-brown, clayey, plastic
*Stratigraphy:* Pleistocene lake silt
*Thickness:* 29 ft (complete thickness not penetrated)
*Elevation of base:* 651 ft
*Type of sample:* Auger of upper 29 ft
*Division of Geological Survey stratigraphic section:* NA

*Ceramic characteristics*
*Forming method used:* Dry press at 1200 psi
*Tempering water:* 14.8%
*Plasticity and workability:* Good
*Wet strength:* Satisfactory
*Dry behavior:* Satisfactory
*Linear drying shrinkage:* 1.2%
*Dry strength:* 232 psi

*Slow-fired properties*

| Temp. (°F) | 24 abs. (%) | 5 abs. (%) | C.A. | L.S. (%) | M.O.R. (psi) | Hard. (Mohs) | Color | Remarks |
|---|---|---|---|---|---|---|---|---|
| 1800 | 15.6 | 16.7 | 0.93 | -0.2 | 780 | 2½ | light orange brown | sl s |
| 1875 | 13.5 | 14.7 | 0.92 | 1.0 | 1020 | 3½ | orange brown | sl s |
| 1950 | 12.0 | 13.4 | 0.90 | 1.2 | 1370 | 5½ | orange brown | sl s |
| 2025 | 7.8 | 9.4 | 0.83 | 4.1 | 1990 | 7- | red brown | |
| 2100 | 2.0 | 3.6 | 0.56 | 6.3 | 3080 | 8- | red brown | sl w, pi, m |
| 2175 | 0.7 | 2.0 | 0.35 | 4.8 | 2820 | 9- | dark red brown | w, b, pi, o |

*Particle-size analysis:* Sand and larger %: 13 Silt %: 57 Clay %: 30
*pH:* 8.3
*Pyrometric cone equivalent:* 11-12
*Other test results:*
*Present and past use:*
*Potential use:* Building brick, face brick, structural tile, conduit, drain tile, terra cotta, sewer pipe, earthenware, artware
*Remarks:*

*Sample no.:* 84-0625
*County:* Washington
*Quadrangle (7½'):* Beverly
*Township:* Waterford
*Section or grid coordinates:* x = 2,240,400 ft, y = 559,300 ft
*Site:* Road cut on SR 76, approximately 1 mi S of Waterford-Beverly bridge
*Lithology:* Clay, brown, silty, plastic, laminated
*Stratigraphy:* Pleistocene lake silt
*Thickness:* 10 ft (base not exposed)
*Elevation of base:* 680 ft
*Type of sample:* Representative channel of lower 5 ft
*Division of Geological Survey stratigraphic section:* NA

*Ceramic characteristics*
*Forming method used:* Dry press at 1200 psi
*Tempering water:* 20.1%
*Plasticity and workability:* Plasticity excessive for good workability
*Wet strength:* Satisfactory
*Dry behavior:* Satisfactory
*Linear drying shrinkage:* 1.9%
*Dry strength:* 173 psi

*Slow-fired properties*

| Temp. (°F) | 24 abs. (%) | 5 abs. (%) | C.A. | L.S. (%) | M.O.R. (psi) | Hard. (Mohs) | Color | Remarks |
|---|---|---|---|---|---|---|---|---|
| 1800 | 19.6 | 20.6 | 0.64 | 1.1 | 1320 | 4½ | light orange brown | sl s, w |
| 1875 | 13.5 | 14.6 | 0.93 | 4.2 | 2020 | 4½ | orange brown | sl s, w |
| 1950 | 10.4 | 11.6 | 0.90 | 7.1 | 2520 | 5 | orange brown | s, w |
| 2025 | 2.9 | 3.2 | 0.91 | 10.5 | 3000 | 5½ | red brown | s, w, m |
| 2100 | 0.3 | 0.3 | 1.00 | 11.0 | 3260 | 9- | dark red brown | w, m |
| 2175 | 2.0 | 11.4 | 0.18 | 0.0 | 2570 | 9- | dark red brown | b, w, o |

*Particle-size analysis:* Sand and larger %: 0 Silt %: 43 Clay %: 57
*pH:* 8.7
*Pyrometric cone equivalent:*
*Other test results:* Plastic limit 23%, liquid limit 52%
*Present and past use:*
*Potential use:* Artware, light weight aggregate, modeling clay, bonding clay
*Remarks:* Moderate strength over long temperature range

*Sample no.:* 84-0626
*County:* Washington
*Quadrangle (7½'):* Marietta
*Township:* Fearing
*Section or grid coordinates:* SE¼ of SE¼ sec. 20
*Site:* Terrace on Zimmer property, approximately 2 mi NE of Marietta
*Lithology:* Silt, brown to reddish-brown, very plastic, clayey, very slightly calcareous
*Stratigraphy:* Pleistocene lake silt
*Thickness:* 34 ft (complete thickness not penetrated)
*Elevation of base:* 616 ft
*Type of sample:* Auger of upper 34 ft
*Division of Geological Survey stratigraphic section:* NA

*Ceramic characteristics*
*Forming method used:* Dry press at 1200 psi (for extrusion data see note fig. 36, p. 74)
*Tempering water:* 15.1%
*Plasticity and workability:* Plasticity high
*Wet strength:* Satisfactory
*Dry behavior:* Satisfactory
*Linear drying shrinkage:* 1.1%
*Dry strength:* 230 psi

*Slow-fired properties*

| Temp. (°F) | 24 abs. (%) | 5 abs. (%) | C.A. | L.S. (%) | M.O.R. (psi) | Hard. (Mohs) | Color | Remarks |
|---|---|---|---|---|---|---|---|---|
| 1800 | 16.4 | 17.9 | 0.92 | 0.2 | 1150 | 3½ | light orange brown | s |
| 1875 | 12.6 | 14.0 | 0.90 | 1.2 | 1580 | 5 | orange brown | s |
| 1950 | 10.0 | 11.8 | 0.85 | 1.9 | 2070 | 5 | orange brown | s, w |
| 2025 | 8.3 | 10.9 | 0.76 | 4.0 | 2520 | 6 | red brown | s, w |
| 2100 | 3.4 | 5.9 | 0.58 | 7.8 | 4320 | 8 | red brown | w, m |
| 2175 | 1.4 | 3.3 | 0.42 | -0.9 | 2330 | 9 | brown | w, o |

*Particle-size analysis:* Sand and larger %: 7 Silt %: 57 Clay %: 36
*pH:* 8.3
*Pyrometric cone equivalent:* 8
*Other test results:* Plastic limit 19%, liquid limit 36%
*Present and past use:*
*Potential use:* Building brick, face brick, structural tile, terra cotta sewer pipe, drain tile, artware
*Remarks:* Good strength over long range of temperature

*Sample no.:* 84-0626
*County:* Washington
*Quadrangle (7½'):* Marietta
*Township:* Fearing
*Section or grid coordinates:* SE¼ of SE¼ sec. 20
*Site:* Terrace on Zimmer property, approximately 2 mi NE of Marietta
*Lithology:* Silt, brown to reddish-brown, very plastic, clayey, very slightly calcareous
*Stratigraphy:* Pleistocene lake silt
*Thickness:* 34 ft (complete thickness not penetrated)
*Elevation of base:* 616 ft
*Type of sample:* Auger of upper 34 ft
*Division of Geological Survey stratigraphic section:* NA

*Ceramic characteristics*
*Forming method used:* De-aired extrusion
*Tempering water:* 25.7%
*Plasticity and workability:* Very good
*Wet strength:* Slightly low but adequate
*Dry behavior:* Very slight warping
*Linear drying shrinkage:* 7.2%
*Dry strength:* 531 psi

*Slow-fired properties*

| Temp. (°F) | 24 abs. (%) | 5 abs. (%) | C.A. | L.S. (%) | M.O.R. (psi) | Hard. (Mohs) | Color | Remarks |
|---|---|---|---|---|---|---|---|---|
| 1800 | 15.8 | 18.0 | 0.88 | 0.0 | 860 | 2+ | light orange brown | very sl s |
| 1875 | 14.7 | 16.6 | 0.89 | 0.3 | 1250 | 4+ | orange brown | very sl s |
| 1950 | 11.6 | 13.7 | 0.85 | 1.5 | 2640 | 5½ | orange brown | very sl s |
| 2025 | 8.5 | 10.9 | 0.78 | 2.9 | 2650 | 6 | red-brown | very sl s |
| 2100 | 0.6 | 0.7 | 0.86 | 6.8 | 3900 | 7 | dark red brown | m |
| 2175 | 0.6 | 9.1 | 0.07 | 3.4 | 1368 | 8+ | dark red brown | b, w, o |

*Particle-size analysis:* Sand and larger %: 7 Silt %: 57 Clay %: 36
*pH:* 8.3
*Pyrometric cone equivalent:* 8
*Other test results:* Plastic limit 19%, liquid limit 36%
*Present and past use:*
*Potential use:* Building brick, face brick, structural tile, terra cotta, sewer pipe, drain tile, artware
*Remarks:* Good strength over long range of temperature

*Sample no.:* 84-0627
*County:* Washington
*Quadrangle (7½'):* Belmont
*Township:* Lawrence
*Section or grid coordinates:* NW¼ of NE¼ sec. 25
*Site:* Terrace on Master property, near Sitka
*Lithology:* Silt, medium-brown, clayey, sandy
*Stratigraphy:* Pleistocene lake silt
*Thickness:* 30 ft (complete thickness not penetrated)
*Elevation of base:* 620 ft
*Type of sample:* Auger of upper 30 ft
*Division of Geological Survey stratigraphic section:* NA

*Ceramic characteristics*

*Forming method used:* Dry press at 1200 psi
*Tempering water:* 17.5%
*Plasticity and workability:* Plasticity moderately high
*Wet strength:* Satisfactory
*Dry behavior:* Slight cracking
*Linear drying shrinkage:* 3.2%
*Dry strength:* 195 psi

*Slow-fired properties*

| Temp. (°F) | 24 abs. (%) | 5 abs. (%) | C.A. | L.S. (%) | M.O.R. (psi) | Hard. (Mohs) | Color | Remarks |
|---|---|---|---|---|---|---|---|---|
| 1800 | 14.6 | 16.0 | 0.91 | 0.5 | 730 | 3½ | light orange brown | w, s |
| 1875 | 12.6 | 14.0 | 0.90 | 0.7 | 850 | 4+ | orange brown | w, s |
| 1950 | 10.0 | 11.8 | 0.85 | 2.6 | 1180 | 4½ | orange brown | w, s |
| 2025 | 8.3 | 10.1 | 0.82 | 3.3 | 1420 | 5½ | red brown | w |
| 2100 | 3.4 | 5.9 | 0.58 | 5.0 | 2150 | 7 | red brown | w, m |
| 2175 | 1.4 | 3.3 | 0.42 | 4.7 | 2780 | 8½ | dark red brown | w, sl o |

*Particle-size analysis:* Sand and larger %: 21 Silt %: 44 Clay %: 35
*pH:* 8.3
*Pyrometric cone equivalent:*
*Other test results:*
*Present and past use:*
*Potential use:* Building brick, face brick, structural tile, terra cotta, sewer pipe, drain tile
*Remarks:*

*Sample No. 49*
*Tests of Creston Red shale from pit of Marietta Shale Brick Company,*
*[eastern edge of sec. 36] Marietta, Washington County*

*Physical properties, determined by Chester R. Austin*
*Properties in green state*

Workability: This material has good plasticity. A good column is extruded from the die.
Time of slaking: 23.78 minutes.
Water of plasticity: 19.03 per cent.
Dry shrinkage:
  Volume: 16.51 per cent.
  Linear: 5.23 per cent.
Drying behavior: Extreme care is necessary in drying to avoid cracking.
Dry modulus of rupture: 573 pounds per square inch.

*Firing behavior*

| Cone | Apparent porosity Per cent | Volume shrinkage Per cent | Calculated linear shrinkage Per cent | Absorption Per cent | Bulk specific gravity | Apparent specific gravity |
|---|---|---|---|---|---|---|
| 06 | 14.30 | 13.72 | 4.4 | 6.50 | 2.20 | 2.57 |
| 04 | 6.59 | 17.55 | 5.5 | 2.83 | 2.32 | 2.49 |
| 02 | 6.04 | 19.15 | 6.0 | 2.56 | 2.36 | 2.52 |
| 1 | 5.00 | 20.17 | 6.3 | 2.10 | 2.38 | 2.51 |
| 3 | 3.47 | 20.60 | 6.4 | 1.45 | 2.39 | 2.48 |
| 5 | 9.29 | 17.82 | 5.6 | 0.39 | 2.32 | 2.35 |
| 7 | 8.89 | 7.43 | 2.4 | 4.27 | 2.07 | 2.28 |

*Fired modulus of rupture:*
  Cone 02, 4,626 pounds per square inch.
  Cone 3, 5,437 pounds per square inch.
*Fired specific impact strength:*
  Cone 03, 1.64 centimeter kilograms per square centimeter.
  Cone 3, 1.19 centimeter kilograms per square centimeter.
*Fired crushing strength:* Cone 3, 14,853 pounds per square inch.
*Best firing range:* Cone 08 to cone 3.
*Overfiring temperature:* Cone 5.
*Pyrometric cone equivalent:* Cone 9.

*Scumming:* Scum occurs on trials fired to cone 01 and lower but no scum is apparent on trials fired above cone 01. One pound of $BaCO_3$ per ton of material is necessary to prevent scumming.

*Salt glazing:* A good salt glaze is produced at both 2,100°F. and 2,050°F. The color at both temperatures is a yellow and reddish brown mottle on a very dark yellowish green background. A glaze is not produced at 2,100°F. on material to which $BaCO_3$ has been added.

*Utilization:* This material was being utilized for the production of face brick. Other possibilities for utilization are common brick, drain tile, and hollow tile. The fired material develops a good red color at cone 04.

# LIMESTONE

## GENERAL STATEMENT

Limestone was formerly produced in small quantities in Washington County, but has not been quarried on a commercial basis since 1959[4]. In that year 86,100 tons of limestone were reported to have been quarried from the Benwood-Uniontown sequence in Waterford Township. There have been a number of small limestone quarries in the general vicinity of the village of Waterford in northern and eastern Wesley Township. Table 7 lists the known former quarries, the unit mined, and the quarried thickness.

Those limestones which may have economic potential and which appear at the surface in Washington County are all considered to be of freshwater origin and are confined to the uppermost Conemaugh and the Monongahela Groups. These limestones are generally quite impure and differ greatly from place to place in thickness and distribution. Normally these units are sequences of very hard dense gray limestone lenses interbedded with calcareous shale or mudstone and, less commonly, sandstone partings.

Freshwater limestones normally do not have the requisite quality for high-grade agricultural lime or road metal; in general the argillaceous content of such stone is quite high and the calcium carbonate content relatively low. These limestones may, however, give limited service in both of these areas. There are numerous reports of farmers crushing limestone from thin ledges and boulders for use on their fields. This practice was apparently fairly common during the depression of the 1930's and before good agricultural lime was available in quantity in the county. The numerous calcareous shale and mudstone partings tend to increase the overall argillaceous content of the mined product; they also contribute to the problems of mining. Relatively large amounts of silica, alumina, iron, and magnesium in these limestones seriously restrict their use in cement, flux stone, and glass manufacture and for other conventional limestone products.

A road stone satisfactory for use on county and township roads can be produced from some of these limestones. In the western part of the county the upper portion of the Benwood-Uniontown sequence has been used for this purpose and to a limited extent for agricultural lime (table 7).

There are four limestones which may have limited value as sources of stone. Three of these units are exposed at the surface; they are, in stratigraphic order from the base, the Upper Pittsburgh and Redstone limestones and a portion of the Benwood-Uniontown sequence. The other unit which may have some economic potential is the Maxville Limestone, which is present at depth in both the eastern and western parts of the county. Other limestones exposed in the area cannot, because of thinness, erratic distribution, or quality, be considered to have any value other than stratigraphic significance.

[4] One company reported production in 1973, 1974, and 1975 in Adams Township.

## DESCRIPTION OF UNITS

### MAXVILLE LIMESTONE

The Maxville Limestone was present in oil and gas well samples at 10 different localities in the county (fig. 24). This unit was identified also in a few wells in eastern Athens County. Lamborn (1945), working from drillers' records, indicated the presence of the Maxville in eastern Newport, Independence, Ludlow, Grandview, Liberty, Barlow, and Decatur Townships. The authors, using well samples not available to Lamborn, would add eastern Lawrence, Wesley, Palmer, northwestern Fairfield, and western Watertown Townships and would delete Liberty Township from Lamborn's list.

The elevation of the limestone ranges from about 300 feet below sea level along the Athens-Washington County boundary to approximately 650 feet below sea level along the Ohio River in Grandview Township (fig. 24). In both the eastern and western areas the Maxville is at depths of 1,000 to 1,200 feet below the lowest valley floors except where the Burning Springs anticline enters Newport Township. There is a very restricted area on the axis and flanks of the arch where the limestone is about 700 feet below the valley of the Ohio River.

The Maxville is as much as 65 feet thick in sec. 36, Independence Township, and sec. 22E, Newport Township. Average thickness for the county is about 36 feet; however, rapid lateral changes in thickness are to be expected because of extensive post-Mississippian erosion. Throughout the center portion of the county (fig. 24) the limestone is completely absent.

Rittenhouse (1949, p. 1705), speaking of the Maxville

TABLE 7.—*Limestone quarry locations in Washington County, Ohio*

| Township | Location | Unit quarried | Quarried thickness | Uses | Remarks |
|---|---|---|---|---|---|
| Waterford | ½ mi SW of Muskingum River and about 2 mi NW of Waterford | Upper portion of Benwood-Uniontown sequence | 11 ft 3 in | Road metal | |
| Waterford | 1¼ mi SW of Waterford along Wolf Creek; formerly quarried in creek bed | Upper portion of Benwood-Uniontown sequence | 7 ft 11 in | Agricultural lime | See O.G.S. chemical analysis 378, p. 113 |
| Waterford | ½ mi N of Beverly near Ohio Rte. 77 | Upper portion of Benwood-Uniontown sequence | Not known | Agricultural lime, road metal | |
| Wesley | N½ of the SW¼ sec. 23, on headwaters of Laurel Run | Top of Benwood-Uniontown sequence | 7 ft 3 in | Agricultural lime, road metal | |
| Wesley | SW¼ of the NW¼ sec. 26N, on tributary to Coal Run | Top of Benwood-Uniontown sequence | 8 ft 8 in | Agricultural lime, road metal | See O.G.S. chemical analysis 405, p. 114 |

correlative in West Virginia, stated:

> Beds composed of quartz sand, lime sand, and oolites in varying proportions occur at several horizons in the Greenbrier formation. These beds are calcareous sandstones in which the sand grains, of both quartz and carbonate, were transported to their place of deposition by waves, or by currents of wind or water. These fragmental or clastic beds occur at definite horizons in the Greenbrier formation and are separated by beds of fine-grained limestone in which no quartz sand occurs and in which the outlines of lime sand grains and oolites are indistinct or absent.

The authors found the Maxville (Greenbrier of above quote) of Washington County essentially as described by Rittenhouse, but made no effort to correlate the clastic zones either within the county or across the border into West Virginia.

A shaft, to limestone, of over 2,000 feet has operated in Ohio, and it is not beyond the realm of possibility to shaft mine the Maxville in Washington County. However, three factors would be against such mining: (1) purity of the unit, (2) thickness of the unit, and (3) depth. The purity of the unit in Washington County is unknown, but the presence of sand and oolite lenses and stringers would suggest a silica content probably above desired levels. The irregular thickness of the bed would necessitate considerable coring to prove an area of mineable reserves. Lastly, the depth of the unit is such that cost of shafting to reach the stone would be prohibitive under current economic conditions. Future needs and economics may make it profitable to mine the formation.

## UPPER PITTSBURGH LIMESTONE

The Upper Pittsburgh limestone, which lies immediately below the Pittsburgh coal and is found in parts of Adams, Aurelius, Fearing, Lawrence, Ludlow, Newport, and Salem Townships, is a multiple-bedded zone of limestone and calcareous shales with an aggregate thickness of 15 to 16 feet in many places. Commonly, however, limestone will account for less than half the thickness of the zone. Lenses of dense hard gray limestone range from a few inches to about 3 feet in thickness. The following section illustrates the multibedded character of the unit.

O.G.S. 8220, Lawrence Twp., SE¼ of the SE¼ of the SW¼ sec. 16, Belmont 7½- and Marietta 15-minute quadrangles. Section measured at south end of bridge on Ohio Rte. 7 over Fifteen Mile Creek. Measured by A. T. Cross and W. H. Smith. Base elevation 623 feet (topographic map).

| | *ft* | *in* | *ft* | *in* |
|---|---|---|---|---|
| *Description reworded slightly from original* | | | | |
| Coal zone, PITTSBURGH | 4 | 1 | 40 | 0 |
| Limestone, walnut brown, leached; abundant ostracods | 0 | 3 | 35 | 11 |
| Limestone, dark-blue-gray to black, silty; pelecypods | 1 | 4 | 35 | 8 |
| Clay-shale, gray; weathers tan | 1 | 5 | 34 | 4 |
| Coal, shaly, and coaly shale | 0 | 3 | 32 | 11 |
| Limestone, coaly | 0 | 3 | 32 | 8 |
| Limestone, dark-gray, hard, nodular; thickness irregular | 0 | 6 | 32 | 5 |
| Shale, gray, silty, calcareous; weathers tan | 1 | 10 | 31 | 11 |
| Limestone, gray, hard, nodular; two or three beds with thin shale partings | 2 | 0 | 30 | 1 |
| Shale, gray; numerous irregularly distributed limestone nodules | 4 | 4 | 28 | 1 |
| Limestone, gray, conglomeratic; weathers creamy white; thickness very irregular | 2 | 3 | 23 | 9 |
| Shale, gray, highly calcareous, iron-stained; thickness irregular | 1 | 4 | 21 | 6 |
| Limestone, nodular; thickness very irregular. UPPER PITTSBURGH | 0 | 4 | 20 | 2 |
| Shale, gray, highly calcareous | 0 | 10 | 19 | 10 |
| Concealed (to Fifteen Mile Creek) | 19 | 0 | 19 | 0 |

It may be seen from the foregoing section that, of a 16-foot 11-inch zone, only 6 feet 11 inches is actually bedded limestone. It may also be noted that the thickest single limestone bed is only 2 feet 3 inches. Lamborn (1951, p. 353) stated that the unit is not known to have been utilized in the county. The limited outcrop area, lack of thick limestone beds, irregular thicknesses, and interbedded shales and mudstones all greatly reduce the economic potential of this unit.

## REDSTONE LIMESTONE

The Redstone limestone in Washington County lies directly over or within a few feet of the Pittsburgh coal and has essentially the same distribution (pl. 1).

This unit is a series of interbedded shale, mudstone, and limestone lenses. The limestone ranges from dense to shaly, and the color ranges from light to very dark gray. In many places nonlimestone interbeds make up the majority of the unit's thickness.

The Redstone is generally thicker and has a greater aggregate thickness of limestone than does the older Upper Pittsburgh. Aggregate limestone thicknesses of 7 to 8 feet are fairly common in Salem Township, and limestone beds totalling 5 to 6 feet are not uncommon in Lawrence, Liberty, and Independence Townships. Two stratigraphic sections illustrate the general nature of this unit:

O.G.S. 8815, Salem Twp., x = 2,316,900 feet, y = 573,000 feet, Lower Salem 7½- and Macksburg 15-minute quadrangles. Section measured in stream and along road to junction at elevation 1,002 feet, 1.1 mi. NE of Lower Salem. Measured by G. Bell. Base elevation 702 feet (barometer).

| | *ft* | *in* | *ft* | *in* |
|---|---|---|---|---|
| *Units 25 through 101 omitted* | | | | |
| REDSTONE limestone, elevation top of unit 725 feet | | | | |
| 24. Limestone, light- and dark-gray, banded, argillaceous; abundant ostracods | 0 | 8 | 8 | 2 |
| 23. Limestone, gray, argillaceous; weathers light gray and platy | 0 | 9 | 7 | 6 |
| 22. Limestone, gray to dark-gray; dense, hard, and conglomeratic at top; shaly and argillaceous at base | 0 | 10 | 6 | 9 |
| 21. Limestone, dark-gray, dense, very hard; weathers yellow brown | 0 | 9 | 5 | 11 |
| 20. Limestone, gray, dense, hard | 0 | 10 | 5 | 2 |
| 19. Limestone, medium-gray to buff, dense, very hard; weathers yellow brown; two massive ledges | 1 | 3 | 4 | 4 |
| 18. Limestone, gray to dark-gray, dense, thin- to shaly bedded, slightly argillaceous | 1 | 1 | 3 | 1 |
| 17. Limestone, light-gray to buff, dense, very hard, massive; weathers yellow brown | 1 | 4 | 2 | 0 |
| 16. Limestone, gray, argillaceous, shaly; base not exposed | 0 | 8 | 0 | 8 |
| *Units 1 through 14 omitted* | | | | |

The following section and chemical analysis were published by Lamborn (1951, p. 353):

O.G.S. 12833, Liberty Twp., E center sec. 14, Dalzell 7½- and Macksburg 15-minute quadrangles. Section measured and sampled along Sycamore Fork. Measured by R. Lamborn. O.G.S. chemical analysis 385.

| | ft | in | ft | in |
|---|---|---|---|---|
| *Approximately 16 feet of section omitted* | | | | |
| REDSTONE limestone | | | | |
| Limestone, bluish-gray, hard; sampled | 0 | 8 | 13 | 6 |
| Shale, calcareous; not sampled | 0 | 4 | 12 | 10 |
| Limestone, bluish-gray, hard, compact; sampled | 0 | 4 | 12 | 6 |
| Clay shale; not sampled | 0 | 2 | 12 | 2 |
| Limestone, bluish-gray, hard; sampled | 0 | 6 | 12 | 0 |
| Clay shale; not sampled | 0 | 1 | 11 | 6 |
| Limestone, bluish-gray, hard; sampled | 1 | 0 | 11 | 5 |
| Shale, calcareous; not sampled | 0 | 10 | 10 | 5 |
| Limestone, bluish-gray, hard; sampled | 0 | 6 | 9 | 7 |
| Shale, calcareous; a few lens-shaped layers of limestone; not sampled | 1 | 4 | 9 | 1 |
| Limestone, bluish-gray, hard, compact; sampled | 0 | 9 | 7 | 9 |
| Shale, calcareous; not sampled | 0 | 3 | 7 | 0 |
| Limestone, bluish-gray, hard; sampled | 0 | 8 | 6 | 9 |
| Shale, carbonaceous; not sampled | 0 | 10 | 6 | 1 |
| Limestone, bluish-gray, hard; sampled | 0 | 4 | 5 | 3 |
| Shale, bluish-gray, calcareous; not sampled | 0 | 5 | 4 | 11 |
| Limestone, bluish-gray, hard, compact; sampled | 1 | 0 | 4 | 6 |
| Clay shale, bluish-gray; not sampled | 2 | 2 | 3 | 6 |
| Coal, PITTSBURGH | 1 | 4 | 1 | 4 |

*O.G.S. chemical analysis 385:*

| | percent |
|---|---|
| Silica, $SiO_2$ | 9.10 |
| Alumina, $Al_2O_3$ | 2.98 |
| Ferric oxide, $Fe_2O_3$ | 1.53 |
| Ferrous oxide, FeO | 1.07 |
| Iron disulfide, $FeS_2$ | <0.01 |
| Magnesium oxide, MgO | 3.08 |
| Calcium oxide, CaO | 43.28 |
| Strontium oxide, SrO | <0.01 |
| Barium oxide, BaO | 0.098 |
| Sodium oxide, $Na_2O$ | 0.17 |
| Potassium oxide, $K_2O$ | 0.38 |
| Water, hydroscopic, $H_2O-$ | 0.10 |
| Water, combined, $H_2O+$ | 0.28 |
| Carbon dioxide, $CO_2$ | 37.46 |
| Titanium dioxide, $TiO_2$ | 0.15 |
| Phosphorus pentoxide, $P_2O_5$ | 0.05 |
| Sulfur trioxide, $SO_3$ | 0.15 |
| Carbon, organic, C | 0.21 |
| Manganous oxide, MnO | 0.02 |
| Hydrogen, organic, H | 0.03 |

The Redstone limestone suffers from the same deficiencies as most freshwater limestones in this region: low purity, irregular thickness, and interbedded nonlimestone materials. The parts of the county having the greatest potential for mining of this unit would be the areas of relatively thick limestone near Whipple and Lower Salem in Salem Township.

## BENWOOD-UNIONTOWN SEQUENCE

The Benwood-Uniontown sequence in Washington County is from approximately 50 to slightly over 100 feet thick. The unit is composed of a complex sequence of thin limestone beds, calcareous shales, limy nodular mudstones, and, less commonly, sandstone lenses. In Washington County the sequence is dominated by the limy nodular mudstones; the limestone lenses are commonly thin, impure, and widely spaced. Individual limestone beds generally do not exceed 3 to 5 feet in thickness. Locally, however, portions of this sequence present possibilities for quarry operations; of the three outcrop units considered in this discussion the Benwood-Uniontown offers the greatest potential for utilization.

This sequence has been quarried along the Muskingum River in Waterford Township and along Wolf Creek in Waterford and Wesley Townships (table 7). In this general vicinity beds of limestone with relatively thin shale stringers aggregate 7 to 12 feet in thickness. This unit is currently being quarried on a small scale in adjacent Morgan County. Lamborn (1951, p. 355) published chemical analyses for samples taken from two former quarry localities in this general region. The results are presented here with lithologic descriptions of the sampled beds:

O.G.S. 2882A, Waterford Twp., x = 2,238,500 feet, y = 557,500 feet, Beverly 7½- and Caldwell 15-minute quadrangles. Section in old quarry of the Waterford Quarries Company just east of road fork 1¼ miles southwest of Waterford. Measured by R. E. Lamborn. O.G.S. chemical analysis 378.

| | ft | in | ft | in |
|---|---|---|---|---|
| BENWOOD-UNIONTOWN sequence | | | | |
| Limestone, nodular; not sampled | 0 | 6 | 11 | 1½ |
| Shale, calcareous; not sampled | 0 | 2 | 10 | 7½ |
| Limestone, nodular; not sampled | 1 | 0 | 10 | 5½ |
| Shale, calcareous; not sampled | 1 | 0 | 9 | 5½ |
| Limestone, bluish- to brownish-gray, hard; one layer; sampled | 2 | 0 | 8 | 5½ |
| Limestone, gray, dense, somewhat brecciated; sampled | 0 | 7 | 6 | 5½ |
| Limestone, light-buff; embedded angular bluish-gray fragments; sampled | 1 | 0 | 5 | 10½ |
| Limestone, bluish- to brownish-gray, dense; sampled | 1 | 0 | 4 | 10½ |
| Shale, calcareous; not sampled | 0 | ½ | 3 | 10½ |
| Limestone, bluish-gray, dense; sampled | 0 | 10 | 3 | 10 |
| Limestone, bluish-gray, dense, brittle; sampled | 1 | 6 | 3 | 0 |
| Limestone, bluish-gray; not sampled | 1 | 6 | 1 | 6 |

*O.G.S. chemical analysis 378:*

| | percent |
|---|---|
| Silica, $SiO_2$ | 11.11 |
| Alumina, $Al_2O_3$ | 2.28 |
| Ferric oxide, $Fe_2O_3$ | 0.02 |
| Ferrous oxide, FeO | 0.93 |
| Iron disulfide, $FeS_2$ | <0.01 |
| Magnesium oxide, MgO | 7.14 |
| Calcium oxide, CaO | 37.03 |
| Strontium oxide, SrO | <0.01 |
| Barium oxide, BaO | 0.12 |
| Sodium oxide, $Na_2O$ | 0.02 |
| Potassium oxide, $K_2O$ | <0.01 |
| Water, hydroscopic, $H_2O-$ | 0.16 |
| Water, combined, $H_2O+$ | 3.25 |
| Carbon dioxide, $CO_2$ | 37.34 |
| Titanium dioxide, $TiO_2$ | 0.01 |
| Phosphorus pentoxide, $P_2O_5$ | 0.03 |
| Sulfur trioxide, $SO_3$ | 0.06 |
| Manganous oxide, MnO | 0.09 |
| Carbon, organic, C | 0.39 |
| Hydrogen, organic, H | 0.05 |

O.G.S. 12834, Wesley Twp., NW¼ sec. 26, Chesterhill 7½- and Chesterhill 15-minute quadrangles. Outcrop along a ravine on the E. L. Waite property. Measured by R. E. Lamborn. O.G.S. chemical analysis 405.

| | ft | in | ft | in |
|---|---|---|---|---|
| BENWOOD-UNIONTOWN | | | | |
| Limestone, light-brownish-gray, dense; with veinlets of calcite | 1 | 0 | 8 | 8 |
| Shale, calcareous | 0 | 1 | 7 | 8 |

| | | | | |
|---|---|---|---|---|
| Limestone, light-brownish-gray, dense; with veinlets of calcite | 0 | 11 | 7 | 7 |
| Shale, olive, calcareous | 1 | 11 | 6 | 8 |
| Limestone, dense, hard | 0 | 6 | 4 | 9 |
| Clay shale | 0 | 2 | 4 | 3 |
| Limestone, dense, argillaceous, brittle; flintlike fracture | 1 | 5 | 4 | 1 |
| Shale, olive-gray, calcareous | 1 | 6 | 2 | 8 |
| Limestone, dense, argillaceous | 0 | 2 | 1 | 2 |
| Shale, bluish, argillaceous | 1 | 0 | 1 | 0 |

*O.G.S. chemical analysis 405:*

| | *percent* |
|---|---|
| Silica, $SiO_2$ | 8.69 |
| Alumina, $Al_2O_3$ | 1.72 |
| Ferric oxide, $Fe_2O_3$ | 0.32 |
| Ferrous oxide, FeO | 0.89 |
| Iron disulfide, $FeS_2$ | 0.07 |
| Magnesium oxide, MgO | 5.49 |
| Calcium oxide, CaO | 42.55 |
| Sodium oxide, $Na_2O$ | 0.09 |
| Potassium oxide, $K_2O$ | 0.30 |
| Water, hydroscopic, $H_2O-$ | 0.13 |
| Water, combined, $H_2O+$ | 0.64 |
| Carbon dioxide, $CO_2$ | 38.85 |
| Titanium dioxide, $TiO_2$ | 0.07 |
| Phosphorus pentoxide, $P_2O_5$ | 0.03 |
| Sulfur trioxide, $SO_3$ | 0.03 |
| Manganous oxide, MnO | 0.10 |

# OIL AND GAS

## GENERAL STATEMENT

Washington County figured prominently in the early days of the petroleum industry in Ohio. Oil and gas were encountered in the drilling of brine wells in the vicinity as early as 1819. Hildreth (1826, p. 5) reported that in 1819 a brine well drilled on the west bank of Duck Creek, 4 or 5 miles above the northern boundary of Washington County, in Guernsey (now Noble) County, encountered

> vast quantities of petroleum, or, as it is vulgarly called *"Seneka oil,"* and besides, is subject to such tremendous explosions of gas, as to force out all the water, and afford nothing but gas for several days, [resulting in the well making] little or no salt.

Hildreth also noted of the petroleum that

> It affords a clear brisk light, when burnt this way, and will be a valuable article for lighting the street lamps in the future cities of Ohio.

The gas which was found in these brine wells was in fact a highly desirable by-product of such wells. In those days, before efficient pumping equipment had been developed, the discharge of gas was essential to provide the drive to make the brine flow.

In the early 1800's oil was not used primarily for fuel, light, or lubrication, but rather was noted for its medicinal properties. However, Hildreth (1833, p. 64) mentioned other applications which ultimately became the prime uses:

> It is at this time, in general use among the inhabitants of the county, for saddle bruises, and that complaint called the scratches, in horses. It seems to be peculiarly adapted to the flesh of horses and cures many of their ailments with wonderful certainty and celerity. Flies and other insects have a natural antipathy to its effluvia, and it is used with much effect in preventing the deposit of eggs by the "blowing fly," in the wounds of domestic animals during the summer months. In neighborhoods where it is abundant, it is burned in lamps in place of spermaceti oil, affording a brilliant light but filling the room with its own peculiar odor. By filtering it through charcoal, much of this empyreumatic smell is destroyed and the oil greatly improved in quality and appearance. It is also well adapted to prevent friction in machinery, for being free of gluten, so common to animals and vegetable oils, it preserves the parts to which it is applied, for a long time, in free motion—where a heavy vertical shaft runs in a socket, it is preferable to all or any other articles.

Hildreth (1833, p. 64) also noted:

> A well on Duck Creek, about thirty miles north of Marietta,... furnishes the greatest quantity of [gas of any well] of this region. It was dug in the year 1814, and is four hundred and seventy five feet in depth. Salt water was reached at one hundred and eighty five feet, but not in sufficient quantity; however, no more water was found below this depth.

In the fall of 1860 a producing well was drilled just south of Macksburg in Aurelius Township. This discovery was followed quickly by a producer drilled in 1861 on Cow Run in Lawrence Township. These wells, drilled just one year after Col. Drake's famous well in Pennsylvania, mark the real beginning of the oil and gas industry in Washington County. Oil and/or gas has since been produced in all 22 townships of the county. Drilling has continued sporadically over the years since 1860, with periodic flurries of activity following each new discovery.

It is conservatively estimated (1968) that there are 8,400 Washington County well records or well locations on file with the Ohio Division of Geological Survey. There were undoubtedly many hundreds or possibly thousands of wells drilled prior to passage of the law requiring that well locations and records be filed with the state. Only a very small number of these 8,400 wells were drilled to units below the Berea Sandstone. A moderate number of wells have been drilled to the Oriskany; this is the lowest stratigraphic unit in the county having commercial production of gas. Most drilling for the Oriskany has been in the western half of the county, with about half of the wells being located in Belpre and Warren Townships. Production in these two townships has been more or less confined to the Putnam field, which represents a northern extension of the Harris District field of Wood County, West Virginia. Table 8 lists the known wells in Washington County that were drilled to the Oriskany or deeper.

Only three wells have been drilled a significant depth below the Oriskany Sandstone. The deepest well in the county is the E. E. Knowlton #1, located in NW¼ sec. 10, Independence Township. This well was started a few feet above the position of the Washington coal and bottomed in the "Red Medina" (Queenston Formation) at a depth of 7,889 feet. Drilling statistics for the period from 1955 to 1968 are given in table 9.

The ratio of productive wells to dry wells as shown in table 9 is rather heavily weighted in favor of the producers. The percentage of producing wells for the period tabulated ranged from 44.1 percent productive in 1965 to 81.5 percent productive in 1968. The high ratio of productive to dry wells from 1962 to 1964 is largely a result of extensive drilling in the then newly discovered Waterford Southeast pool. This high success ratio unfortunately was not accompanied by high production levels.

Reliable figures on oil and gas production for the county are not generally available. Production data given in table 9 are for initial gage and do not reflect the normal decline that most wells show after a period of time. These figures are also somewhat misleading because of a tendency

TABLE 8.—*Wells penetrating the Oriskany or deeper zones in Washington County, Ohio*[1]

| Township | Permit no. | Lease name and well no. | Location | Surface elev. (ft above sea level) | Depth to Oriskany (ft) | | Total depth (ft) | Remarks |
|---|---|---|---|---|---|---|---|---|
| | | | | | Top | Bottom | | |
| Adams | 210 | Augenstein #1 | Lot 49, Bear Creek Allotment | 802 | 4432 | 4436 | 4443 | Show of gas in Berea; water in Oriskany |
| Adams | 1560 | Shantz #1 | Lot 18, Big Run Allotment | 820 | 4114 | ? | 4132 | Dry; water in Oriskany |
| Adams | 1642 | Jackson #1 | Lot 58, Bear Creek Allotment | 1036 | 4627 | ? | 4632 | Show of gas in Berea |
| Aurelius | 268A-1 | Longfellow #22 | SE¼ sec. 7 | 680 | 4205 | 4240 | 4260 | Show of gas in Berea; show of oil with water in Oriskany |
| Barlow | 1546 | Loynachan #1 | NW¼ sec. 27 | 775 | 4027 | 4061 | 4078 | Dry; water in Oriskany |
| Barlow | 1557 | Tretchel #1 | SW¼ sec. 18 | 740 | 4079 | 4108 | 4129 | Show of gas in Berea; show of oil in Oriskany |
| Barlow | 1571 | Stephens #1 | SW¼ sec. 10 | 825 | 4264 | ? | 4303 | Dry |
| Barlow | 1582 | McCoy #1 | NW¼ sec. 6 | 840 | 4304 | 4321 | 4345 | Show of oil in Oriskany |
| Belpre | 1311 | Lamp #1 | Lot 66 | 638 | 4091 | 4108 | 4132 | Gas in Oriskany |
| Belpre | 1488 | Williams #1 | Lot 1013 | 718 | 4119 | 4153 | 4173 | Gas in Oriskany |
| Belpre | 1515 | Houser #1 | SW¼ sec. 8 | 645 | 4224 | ? | 4296 | Show of oil with water in Oriskany |
| Belpre | 1519 | Bell #1 | Lot 62 | 646 | 4058 | 4092 | 4097 | Dry |
| Belpre | 1522 | Walker #1 | Lot 49 | 671 | 4082 | 4126 | 4134 | Gas in Oriskany |
| Belpre | 1528 | Curtis #1 | Lot 51 | 675 | 4098 | 4130 | 5647 | Dry |
| Belpre | 1529 | Walker #1 | Lot 64 | NA[2] | 4008 | 4023 | 4110 | Dry |
| Belpre | 1539 | Douglass #1 | Lot 39 | 703 | 4142 | 4170 | 4174 | Show of gas with water in Oriskany |
| Belpre | 1544 | Brethauer *et al.* #1 | Lot 1013 | 704 | 4114 | ? | 4143 | Gas in Oriskany |
| Belpre | 1545 | Oakes #1 | Lot 64 | 635 | 4094 | ? | 4114 | Gas in Oriskany |
| Belpre | 1694 | Holdren #1 | Lot 1014 | 713 | 4133 | ? | 4150 | Gas in Oriskany |
| Belpre | 1695 | Dunfee #1 | Lot 54 | 822 | 4300 | ? | 4309 | Gas in Berea |
| Belpre | 1696 | Lipps #1 | Lot 1015 | 708 | 4125 | 4140 | 4146 | Gas in Oriskany |
| Belpre | 1698 | Oakes #1 | Lot 64 | 712 | ? | ? | 4123 | Gas in Oriskany |
| Belpre | 1699 | Brethauer #2 | Lot 1019 | 626 | 4056 | ? | 4080 | Gas in Oriskany |
| Belpre | 1700 | Oakes #1 | Lot 58 | 682 | 4117 | ? | 4134 | Gas in Berea and Oriskany |
| Belpre | 1701 | Oakes #1 | Lot 56 | NA | 4116 | ? | 4130 | Dry |
| Decatur | 1538 | Ross-Riddle #1 | SW¼ sec. 8 | 798 | 4035 | ? | 4069 | Show of gas in Berea |
| Decatur | 1991 | Wier #1 | NW¼ sec. 17 | NA | 3863 | ? | 3894 | Dry |
| Fairfield | 2043 | Jarvis #1 | SE¼ sec. 16 | 900 | 3920 | 3945 | 3972 | Dry |
| Fairfield | 2089 | Rowland #1 | NW¼ sec. 4 | 850 | 3959 | | 3969 | Dry; water in Oriskany |
| Independence | C-0027-1-1 | Knowlton #1 | NW¼ sec. 10 | 1001 | 5657[3] | 5750[3] | 7889 | Show of gas in "Big Injun"; show of oil and gas in Oriskany |
| Lawrence | 359 | Hill #1 | SE¼ sec. 25 | 894 | 5121 | 5184 | 5202 | Dry |
| Liberty | 1914 | Scott #1 | NE¼ sec. 20 | 904 | 5090 | 5128 | 6863 | Show of gas in Oriskany |
| Marietta | 369 | Hall #1 | NE¼ sec. 17 | 778 | 4897 | 4965 | 5089 | Show of gas in Oriskany |
| Palmer | 303 | Stollar #1 | Lot 823 | 788 | 3942 | 3973 | 3991 | Show of gas in Berea; water in Oriskany |
| Warren | 2238 | Ammon #1 | NE¼ sec. 29 | 930 | 4548 | 4575 | 4651 | Dry |
| Warren | 2582 | Gustke #1 | NW¼ sec. 14 | 685 | 4434 | 4466 | 4489 | Gas in Oriskany |
| Warren | 2651 | Gustke #1B | NE¼ sec. 15 | 911 | 4677 | 4722 | 4727 | Show of gas in Berea and Oriskany |
| Warren | 2664 | Haythorne Consolidation #1 | NW¼ sec. 19 | 752 | 4450 | 4490 | 4510 | Gas in Oriskany; show of gas in Berea |
| Warren | 2761 | Constitution Stone #1 | Lot 271 | 605 | 4335 | 4376 | 4765 | Gas in Oriskany |
| Warren | 2763 | Union Carbide #1 | SE¼ sec. 14 | 641 | 4423 | 4457 | 4505 | Show of oil and gas in Berea and Oriskany |
| Waterford | 1697 | Miller #1 | Lot 75, Rainbow Creek Allotment | 931 | 4342 | 4364 | 4369 | Show of gas in Oriskany |
| Watertown | 1520 | Arnold #1 | Lot 60, Rainbow Creek Allotment | 895 | 4349 | 4378 | 4399 | Gas in Oriskany |
| Watertown | 1530 | Withington #1 | Lot 4, South Branch Allotment | 850 | 4201 | 4230 | 5800 | Dry |
| Watertown | 1552 | Farley #1 | Lot 29, Rainbow Creek Allotment | 733 | 4308 | ? | 4317 | Show of oil and gas in Oriskany; show of gas in Berea |
| Watertown | 1782 | Arnold #1 | Lot 417 | 884 | 4391 | 4416 | 4430 | Dry |
| Watertown | 1824 | Heiss #1 | Lot 51, Rainbow Creek Allotment | 792 | 4305 | 4323 | 4328 | Gas in Berea |
| Wesley | 2681 | Pahl #1 | SW¼ sec. 2 | 960 | 3805 | 3808 | 5243 | Show of oil in "Red Medina" |

[1] All data from drillers' records; elevations picked from topographic map.
[2] Not available.
[3] Top from drillers' log and bottom from well description by M. C. Kiess.

TABLE 9.–*Wells drilled for oil or gas in Washington County, Ohio, from 1955 to 1968*[1]

| Year | No. of wells: Total | Oil[2] | Gas[2] | Combi-nation | Dry | Percent productive | Total wells drilled in Ohio | Washington County wells as a percent of state total | Reported initial daily production: Oil (bbl) | Gas (MCF) |
|---|---|---|---|---|---|---|---|---|---|---|
| 1968 | 65 | 18 | 15 | 20 | 12 | 81.5 | 1,216 | 5.3 | 936 | 17,405 |
| 1967 | 37 | 10 | 8 | 7 | 12 | 67.6 | 1,246 | 3.0 | 374 | 5,581 |
| 1966 | 64 | 15 | 8 | 24 | 17 | 73.4 | 1,271 | 5.0 | 1,049 | 14,657 |
| 1965 | 44 | 10 | 7 | 14 | 13 | 70.5 | 1,705 | 2.6 | 227 | 7,504 |
| 1964 | 61 | 20 | 18 | 6 | 17 | 72.1 | 2,665 | 2.3 | 187 | 16,560 |
| 1963 | 112 | 49 | 38 | | 25 | 77.7 | 1,155 | 9.7 | 641 | 28,798 |
| 1962 | 163 | 80 | 38 | | 45 | 72.4 | 1,152 | 14.1 | 1,523 | 44,067 |
| 1961 | 59 | 25 | 7 | | 27 | 54.2 | 1,113 | 5.3 | 211 | 1,365 |
| 1960 | 49 | 23 | 3 | | 23 | 53.2 | 1,005 | 4.9 | 202 | 762 |
| 1959 | 43 | 8 | 15 | 4 | 16 | 62.8 | 1,278 | 3.4 | 77 | 1,291 |
| 1958 | 52 | 20 | 7 | 3 | 22 | 57.7 | 1,168 | 4.5 | 184 | 1,471 |
| 1957 | 56 | 23 | 4 | 4 | 25 | 55.4 | 1,041 | 5.4 | 102 | 334 |
| 1956 | 63 | 21 | 5 | 10 | 27 | 57.1 | 1,245 | 5.1 | 196 | 1,024 |
| 1955 | 59 | 14 | 15 | 6 | 24 | 59.3 | 1,234 | 4.8 | 134 | 1,725 |

[1] Data from Ohio Division of Mines, annual reports. Production data for 1969-1974 are:

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 1969 | 21 | 4 | 3 | 6 | 8 | 62.0 | 92.6 | 2.3 | 93 | 4,100 |
| 1970 | 19 | 5 | 7 | 0 | 7 | 63.2 | 1,355 | 1.4 | 12 | 10,437 |
| 1971 | 26 | 4 | 16 | 1 | 5 | 80.8 | 1,238 | 2.1 | 18 | 6,066 |
| 1972 | 26 | 4 | 14 | 5 | 3 | 88.5 | 1,293 | 2.0 | 152 | 14,527 |
| 1973 | 19 | 0 | 11 | 2 | 6 | 68.4 | 1,502 | 1.3 | 2 | 10,171 |
| 1974 | 6 | 0 | 4 | 0 | 2 | 66.7 | 1,766 | 0.3 | 0 | 3,644 |

[2] Wells producing both oil and gas from 1960 through 1963 were classified according to whichever had the greatest initial production.

on the part of many operators to inflate or decrease initial production figures. Wells in this area commonly have relatively high initial production that declines rapidly. Examples of wells going from 240 to 4 or 5 barrels in just a few days are reported by Bownocker (1903, p. 173). Settled production, although generally small, is commonly long lived. Bownocker gave information on production, decline, sands, and history of development for the major fields of Washington County as well as for other parts of the state. A two-year production record (table 10) for two Berea wells in Muskingum Township was made available through the courtesy of Carl Heinrich (personal communication) of Marietta. These two wells are not presented as representing typical decline curves for the Berea.

Adequate data on the value of oil and gas produced yearly in Washington County are difficult to obtain. This difficulty stems largely from the lack of a good production-reporting system. Table 11 gives the value of oil and gas for the years indicated as reported from tax abstracts by the Washington County Auditor to the Ohio Department of Taxation.

## PRODUCING HORIZONS

Stout and others (1935, p. 898-903) listed 19 Pennsylvanian sands that have produced oil and gas in the county. The exact number of commercially producing sands that are assigned to the Pennsylvanian System in Washington County differs, however, from author to author. Drillers in this area have applied as many as 22 names to shallow "pay" sands; others have named as few as 7 producing zones. Some of this confusion arises from differences in definition of commercial sands. However, the principal problem arises from the difficulty in making reliable correlations of these sands.

Records of wells drilled to these shallow sands are notoriously inadequate. Practically none of these records have wellhead elevations, many have vague location descriptions, and most have very poor, if any, descriptions of the strata encountered in the hole. Sample suites from these wells are virtually nonexistent. Many drillers rely on the depths above or below certain "key" beds as guides in identifying the sands. Many of these "key" beds are difficult to identify even for a trained geologist; the geologically untrained driller could be expected to have even more difficulty.

The complex nature of Pennsylvanian stratigraphy is well known. Bownocker (1903, p. 26) recognized the problem of correlating shallow sands when he stated, "Generally the sands are local, and cannot be traced over an area of more than a fraction of a mile." He considered the correlation of drillers' terms with surface terminology in the Pennsylvanian rocks as merely approximations of relative stratigraphic positions. Attempts to apply "layer-cake" geology to these rocks in many cases lead to erroneous conclusions and correlations. Magbee and Alkire (1954, p. 8), speaking of sands lying above the Berea, stated that "generally, they are lenticular bodies without lateral continuity, which may be replaced by shale or siltstone within very short distances."

The oil- and gas-producing sands in Washington County were deposited as an integral part of a complex deltaic system. The many environments of deposition in such a deltaic complex are self-evident and, without considerably more data than are now available, would be almost

TABLE 10.—*Production from two Berea wells in Muskingum Township, Washington County, Ohio, 1963-1965*

| Year | Date | Average daily production (bbl) P-2678[1] | Average daily production (bbl) P-2724[2] |
|---|---|---|---|
| 1963 | Feb. | 11.3 | 4.1 |
| | Mar. | 9.2 | 5.4 |
| | Apr. | 9.9 | 3.3 |
| | May | 8.5 | 2.4 |
| | June | 9.0 | 2.0 |
| | July | 8.9 | 1.9 |
| | Aug. | 8.5 | 2.2 |
| | Sept. | 7.23 | 1.5 |
| | Oct. | 8.46 | 1.35 |
| | Nov. | 7.80 | 1.36 |
| | Dec. | 7.23 | .96 |
| 1964 | Jan. | 8.46 | 1.15 |
| | Feb. | 7.20 | 1.31 |
| | Mar. | 7.01 | 1.10 |
| | Apr. | 7.08 | 1.25 |
| | May | 6.16 | .91 |
| | June | 6.78 | 1.08 |
| | July | 6.23 | .99 |
| | Aug. | 7.98 | .91 |
| | Sept. | 4.92 | .89 |
| | Oct. | 6.90 | .86 |
| | Nov. | 6.29 | .83 |
| | Dec. | 5.89 | .80 |
| 1965 | Jan. | 6.90 | .86 |
| | Feb. | 6.91 | .80 |
| | Mar. | 7.83 | ? |

[1] Wilson #1, lot 5, Rainbow Creek Allotment, Muskingum Township, Washington County; completed November 3, 1962, Berea Sandstone, T.D. 1648 ft.

[2] Rush #1, lot 19, Rainbow Creek Allotment, Muskingum Township, Washington County; completed December 28, 1962, Berea Sandstone, T.D. 1956 ft.

impossible to delineate in the subsurface. The inability to identify depositional areas of beach, bar, channel, and other sand bodies associated with deltas would seriously hamper any attempt at meaningful correlation. Experience with the surface deposits of the county indicates that there are no true "key" beds that can be traced over the entire area. The two units which might be most helpful in establishing the relative stratigraphic position of any given sand are the marine Ames limestone and the Brush Creek shale and limestone. Unfortunately, these units are generally not recognized by drillers. Further confusion is added in the lower portion of the Pennsylvanian by the fact that this

TABLE 11.—*Value of 1958-69 oil and gas production reported from tax abstracts for Washington County, Ohio*

| Year | Amount | Year | Amount |
|---|---|---|---|
| 1969 | $301,840 | 1963 | $339,950 |
| 1968 | 351,060 | 1962 | not reported |
| 1967 | 362,850 | 1961 | 321,830 |
| 1966 | 346,660 | 1960 | 315,680 |
| 1965 | 378,630 | 1959 | 336,600 |
| 1964 | 415,630 | 1958 | 440,220 |

section was deposited over an erosion surface of considerable relief. No attempt has been made, for the reasons given above, to alter or reevaluate earlier correlations of the shallow sands. The authors feel it is sufficient to say that there are numerous oil- and gas-bearing bodies of ill-defined size and shape present throughout the Pennsylvanian rocks of Washington County, and that such bodies may or may not have a genetic relationship to similar bodies in the same relative stratigraphic positions at some other location in the county or state.

The following discussion of the producing zones in Washington County and adjacent areas is reproduced without modification from Stout and others (1935, p. 898-903). Additional discussion of the subsurface stratigraphy based on original research for this report will be found in the chapter on stratigraphy.

## PENNSYLVANIAN SYSTEM

### MONONGAHELA GROUP

*Goose Run sandstone.*—The Goose Run sandstone was named for a gas-bearing zone discovered in 1899-1900 on Goose Run east of Marietta in Marietta Township, Washington County. The bed is correlative with the Sewickley sandstone and has a stratigraphic position closely above the Meigs Creek, Sewickley or Mapletown coal. The rock is medium-fine in texture, open in character, massive in structure, and 10-40 feet thick. It has produced only small quantities of gas in Washington and Monroe counties.

### CONEMAUGH GROUP

*Mitchell sandstone.*—The name Mitchell was applied to a sandstone found on the Mitchell farm in Section 10, Marietta Township, Washington County. The original gas pool was small and was developed during 1899 and 1900. This zone is correlated with the Connellsville sandstone which is found in the upper part of the Conemaugh series, about 90 feet below the Pittsburgh coal. It is open-textured, medium-grained, micaceous sandstone, ranging in thickness from 10 to 50 feet. This zone is not persistent, but local sandstones are known in Athens, Morgan, Washington, Noble, Monroe, and Belmont counties.

*Wolf Creek sandstone.*—The Wolf Creek sandstone of northwestern Washington County seems to be only a local development of the Morgantown sandstone of the Conemaugh series. The zone is very erratic, being much more commonly absent than present. Physically, it changes from fine-grained, bluish gray sandstone to coarse-grained, yellowish gray rock. The thickness ranges between 15 and 25 feet. The position of the Morgantown sandstone or its correlative equivalent is 130-150 feet below the Pittsburgh coal and 40-60 feet above the Ames limestone. This member is only a small producer of gas in southeastern Ohio.

*Vincent sandstone.*—Sandstone lenses without definite stratigraphic designations appear at or near the horizon of the Ames limestone at places in southeastern Ohio. Near Vincent in Barlow Township, western Washington County, one of these stray sandstones, directly on top of the Ames limestone, produced gas and was named Vincent sandstone. No other pools have been found at this horizon in southeastern Ohio.

*Peeker sandstone.*—The Peeker sandstone, of Morgan, Athens, and western Washington counties, is the Saltsburg sandstone, separated from the Cow Run below it by little or no shale break. This dark gas- and oil-bearing sandstone is not the Peeker of the Macksburg area.

*First Cow Run sandstone.*—The First Cow Run, the most prominent producing sandstone in the Conemaugh series of southeastern Ohio, was discovered in 1861, by drilling on Cow Run in southwestern Lawrence Township, Washington County. This zone lies between the Cambridge and Ames limestones or, more precisely, between the Anderson and Barton coals. Where well developed, the sandstone lies on or only a few feet above the Anderson coal. Generally the top of the Cow Run sandstone is almost 60 feet below the Ames limestone and 40 feet above the Cambridge limestone. The thickness of the member ranges from 5 to 40 feet, but averages about 20 feet. It is coarse-grained, loosely cemented, light gray or drab-colored sandstone without definite partings or bedding planes.

The Cow Run sandstone is widely distributed geographically, but is best known from drilling operations in Washington, Morgan, Noble, Athens, and Muskingum counties.

*Buell Run sandstone.*—Along Buell Run southwest of Elba in Sections 20, 21, and 28, Aurelius Township, Washington County, a local lens of sandstone containing gas was found in 1888 and a small pool was developed. The zone seems to lie between the Cambridge and Brush Creek limestones and to have the position of the Buffalo member which is very locally developed, generally thin, but commonly coarse or even pebbly in texture. Elsewhere in southeastern Ohio, there has been no development of consequence at this zone.

*Macksburg 300-Foot sandstone.*—The Macksburg 300-Foot sandstone is the Mahoning sandstone which lies directly on top of No. 7, or Upper Freeport, coal. It has yielded gas and oil in small quantities in Noble, Athens, Meigs, and Washington counties, but elsewhere it has been of little interest as a source of oil or gas.

### ALLEGHENY GROUP

*Second Cow Run or Peeker sandstone.*—In many places the Second Cow Run or Peeker sandstone, originally discovered on Cow Run in Washington County, is correlated with the Lower Freeport sandstone which is the massive stratum that forms the roof of the Middle Kittanning coal, over wide areas in southeastern Ohio. Much confusion, however, exists among the drillers regarding the correlation of this and other sands in the interval between the Brush Creek limestone and the Middle Kittanning coal. The Lower Freeport sandstone is massive in character, medium-coarse in texture, and light gray-to-buff in color. Small gas-bearing areas are scattered over southeastern Ohio in Washington, Noble, and Monroe counties. The first sandstone beneath the No. 5, or Lower Kittanning, coal, called Second Cow Run sand in Morgan, Athens, and Meigs counties, has been a prolific producer of gas.

*Macksburg 500-Foot sandstone.*—The Macksburg 500-Foot sandstone, one of the important producing zones discovered at Macksburg in Washington County in the early sixties, seems to be the Clarion sandstone lying below the Clarion coal and not far above the Putnam Hill limestone. This member is a moderately persistent stratum in large areas in southern and eastern Ohio and ranges in thickness from 10 to 50 feet. The sandstone is commonly light gray in color and rather fine in texture. It has produced gas and oil for many years in parts of Washington, Noble, Morgan, Athens, Meigs, and Monroe counties.

### POTTSVILLE GROUP

*Macksburg 700-Foot sandstone and others.*—The Macksburg 700-Foot, Macksburg Stray, First Germantown, Macksburg 800-Foot, Second Germantown, First Salt, Brill, and Schramm sandstones are local developments of siliceous rocks that occur in a zone immediately above and below the Mercer limestones. In general, these beds are only local lenses. They are gas-bearing chiefly in Washington, Noble, Athens, Meigs, Morgan, and Monroe counties.

*First Salt sandstone.*—In Ohio the most persistent sandstone near the base of the Pennsylvanian system is the Connoquenessing or Massillon member which lies about 70 feet below the Lower Mercer limestone and just above the Quakertown coal. This sandstone is commonly called the Salt or First Salt sand by most drillers. These rocks maintain a thickness of 20-40 feet in wide areas in the southern and eastern parts of the state. Locally, because of the absence of the Sharon members, the Massillon or Salt sandstone lies at or close to the base of the Pottsville series and, therefore, is mistaken for the Sharon conglomerate or Maxton sandstone. In general, the Massillon is coarse-grained sandstone, and in many places the basal part is conspicuously conglomeratic. This bed was the source of brine supplies at the early salt works in southern Ohio, hence, the name Salt sand. The stratum has not been a large gas producer in any field in Ohio, but has given scattered wells from Meigs County on Ohio River to Columbiana County on the Ohio-Pennsylvania line.

*Maxton sandstone.*—The Maxton sandstone of the old Sistersville, West Virginia, pool, is correlated with some certainty as the Sharon conglomerate which occurs at the base of the Pottsville series. The Lower Salt and the Lime sandstones of Monroe County have the same stratigraphic position. The Sharon member occurs only in the pre-Pennsylvanian trough-like basins which were eroded deeply into the Mississippian floor. When the seas of early Pennsylvanian time entered Ohio, they first filled the low depressions with thick beds of quartz sand and pebbles now representing the Sharon conglomerate. The thickness of these deposits ranges from 10 to 200 feet, the texture from that of coarse conglomerate to fine-grained sandstone. The Sharon or Maxton sandstone has yielded some gas in Lawrence, Gallia, Meigs, Athens, Morgan, Washington, Monroe, and Belmont counties, and has possibilities in several others on the east and north.

## MISSISSIPPIAN SYSTEM

### LOGAN GROUP

*Keener sandstone.*—The Keener sandstone, named for an oil-bearing zone discovered on the Keener farm near Sistersville, West Virginia, is correlated as a part of the Vinton member, which is the upper formation of the Logan group of the Waverly. It is separated from the Maxville limestone above and from the Big Injun sandstone below by 10-40 feet of shale. The ordinary thickness of the Keener sandstone ranges from 25 to 35 feet. The zone is composed of alternate layers of fine-to-coarse-grained sandstone, generally open in texture, and varying in color from light gray to bluish gray. The several layers give rise to different gas-bearing horizons and, thus, cause variations in productivity. The Keener sandstone in southeastern Ohio is water-bearing; therefore, production is found on structure. It is one of the chief sources of oil and gas in Monroe and Washington counties and is important also in Morgan, Athens, Noble, Guernsey, and Belmont counties.

### CUYAHOGA FORMATION

*Big Injun sandstone.*—The Big Injun sand, widely known to the drillers in southeastern Ohio and northern West Virginia, is identified as the Black Hand conglomerate which crops out so prominently in western Hocking, central Fairfield, and eastern Licking counties. From these counties the member extends southeastward to Ohio River and far into West Virginia. This zone is absent in southern and eastern Ohio where it is represented by shales containing thin sandstone layers. The general thickness of the Big Injun sandstone is 70-120 feet, but may be as much as 260 feet. It is always coarse-grained and in typical exposures contains many pebbly layers distributed as lenses along bedding and cross-bedding planes. The sandstone zone is porous. The top of the Big Injun sandstone is found 60-175 feet below the Maxville limestone and 350-650 feet above the Berea sandstone. Ordinarily in the main field these intervals are about 125 and 410 feet, respectively. This zone contains large quantities of salt water which in places make the life of the wells short. As a gas-producer the Big Injun sandstone is of most importance in Washington and Monroe counties, less so in Athens, Vinton, Morgan, Muskingum, Noble, Guernsey, and Belmont counties.

*Squaw sandstone.*—The Squaw sandstone is not a definite stratigraphic unit. It may be the lower part of the Black Hand member that has been separated from the main zone by a thin stratum of shale or the top of the Cuyahoga formation. It produces gas only in scattered wells in southeastern Ohio, expecially in southern Monroe and eastern Washington counties.

*Hamden-Weir sandstone.*—In the Mississippian system, sandstones occur with some uniformity in that part of the section 100-200 feet above the Berea sandstone. Through local changes in character and through structural relations, one or more of these layers may become a reservoir for the accumulation of oil or gas. On the outcrop they are known as the Buena Vista sandstones and are best developed in western Scioto, western Pike, and eastern Adams counties. To this horizon, but probably not directly correlative other than to the group, belong the Weir sandstone of West Virginia, the Hamden sandstone of Jackson and Vinton counties, Ohio, and the Welsh Stray of Monroe County. The zone consists of several distinct layers of sandstone separated by shale partings. The thickness of the sandstone layers ranges from a few inches to 4 feet and the texture from fine to medium-coarse. In Ohio the outstanding gas pool is near Hamden in Vinton County.

### BEREA FORMATION

*Berea sandstone.*—The Berea sandstone, known to the driller as the Berea sand or Berea grit, is a name applied by Newberry to sandstones exposed near Berea in Cuyahoga County. The formation crops out in a broad belt extending from Ashtabula County west to Huron and thence south to Adams and Scioto counties on Ohio River. Underground in eastern and southern Ohio, the member is very persistent. In many places a shale layer 1-55 feet thick divides the zone into two divisions. In the lower division occur the Butler Gas, Butler 30-Foot, and Bedford Gas, or Second Berea, sandstones.

The Berea sandstone is easily recognized stratigraphically because (1) it is overlain by the Sunbury shale which is brown-to-brownish black in color and of tough, flaky nature and (2) because it is underlain by the Bedford shale which is soft and clay-like in character and light gray, chocolate, red, or pink in color. In general, the Berea is fine-grained, argillaceous, light-to-bluish gray sandstone. The zone consists of alternate layers of sandstone and shale, the former most numerous. The thickness of the formation ranges from 5 to 200 feet, but averages about 45 feet. It is by far the most important gas-bearing zone of the shallow gas sands and is productive in almost every county in eastern and southern Ohio.

## DEVONIAN SYSTEM

### OHIO SHALE GROUP

*Gordon sandstone.*—In the Macksburg area and in some other parts of eastern Ohio, a thin lens of sandstone, lying 365-400 feet under the Berea, is correlated with Gordon sandstone in West Virginia. It has produced both gas and oil.

*Ohio shale.*—The Ohio shale, the upper division of the Devonian system in the state of Ohio, consists of three divisions, the Huron (Little Cinnamon), the Chagrin, and the Cleveland (Big Cinnamon). The stratigraphic range of any one division is not sharply defined; regionally it varies. The Huron and Cleveland are typically black, highly carbonaceous fissile shales. The Chagrin, or middle division, is gray, siliceous shale, free of organic matter. The Ohio shale is present in three widely separated areas in Ohio: one is found in the eastern part of the state, another in the northwestern corner, and the third is the Bellefontaine outlier. The formation crops out along Lake Erie from Conneaut to Sandusky, thence southward across the state to Buena Vista on Ohio River. The thickness of the Ohio formation ranges from less than 400 feet in Pike County to more than 5,000 feet in Jefferson County. Normally, these shales thicken eastward at the rate of 20-30 feet per mile and 5-15 feet per mile southward.

During the early fifties kerosene was distilled from Ohio shales at Buena Vista. In northeastern Ohio many shallow gas wells have been completed in these shales at depths of 300-600 feet. The best wells gauged 25,000-50,000 cubic feet per day with rock pressures of 40-60 pounds. Here the shale has supplied households with fuel from near-by wells since the seventies.

The gas-bearing area is extensive. The gas seems to be confined to openings in the shales along the joint planes caused by crustal movements. The Ohio shale has yielded scattered gas wells of small output in central Ohio and will probably yield fair returns in a field north of Portsmouth and east of Waverly. In Ohio it produces gas in commercial quantities (1932) from a few small areas in southern Lawrence County. In southeastern Ohio this thick shale formation contains wedges of a few sandstone lenses that are best developed in West Virginia. The Ohio shale is a potential source of both oil and gas.

### ORISKANY FORMATION

*Oriskany sandstone.*—In Ohio the Oriskany formation has been found only in wells drilled in the eastern part of the state. Its geographic distribution is erratic, and the formation is absent in large areas. The thickness of the zone underground ranges from 1 to 100 feet, but commonly is 10-30 feet. The material is fine-grained sand loosely cemented with a calcareous bond. It is known also as the

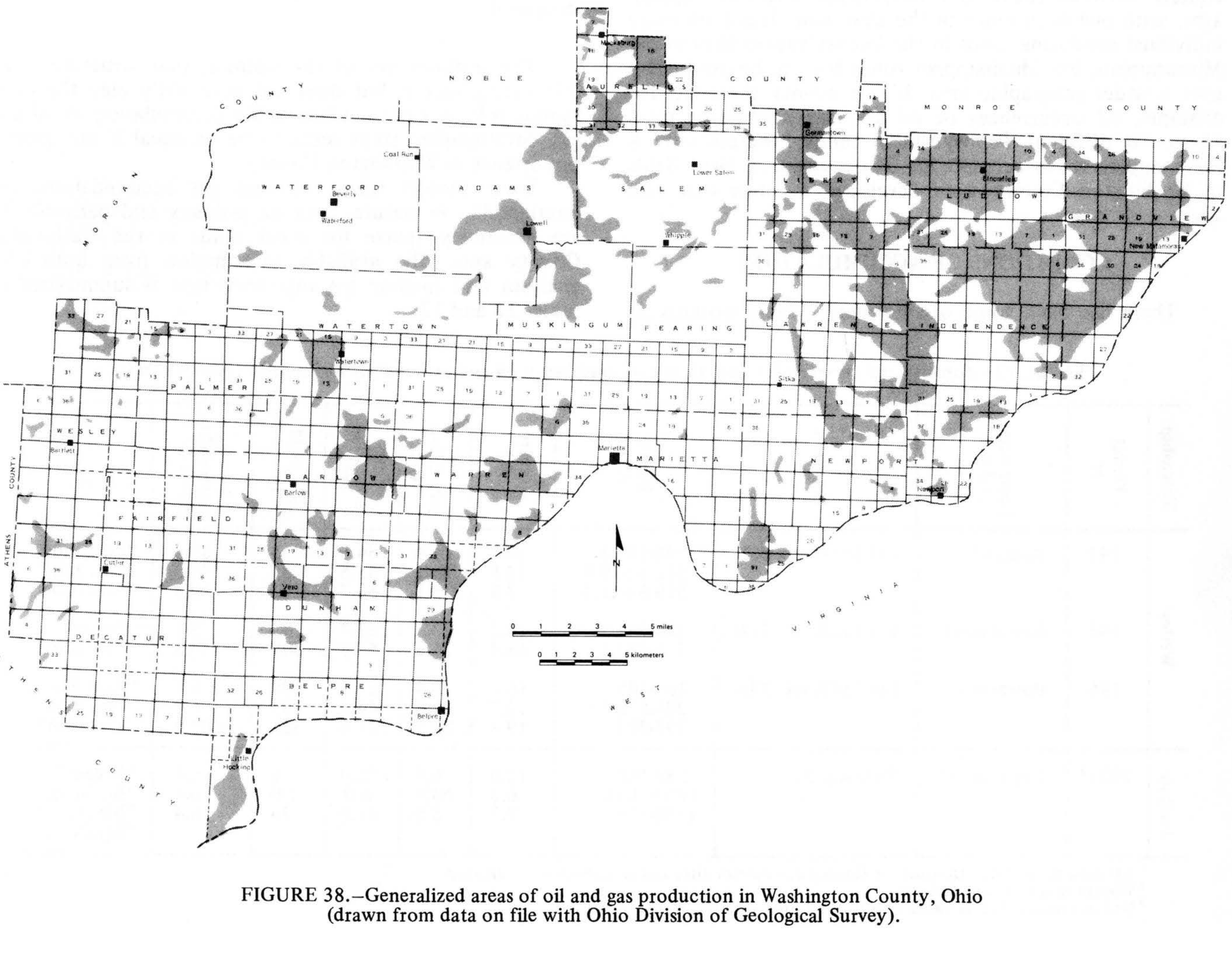



FIGURE 38.—Generalized areas of oil and gas production in Washington County, Ohio (drawn from data on file with Ohio Division of Geological Survey).

Austinburg, Cambridge, and Corniferous Lime sand. The formation is encountered by the drill at 1,950 feet in the Austinburg pool of Ashtabula County; at 3,400 feet in the Cambridge field of Guernsey County; at 3,700 feet in West Township, Columbiana County; and at 5,200 feet near Steubenville in Jefferson County. Production from the Oriskany sandstone has been chiefly gas. To date (1932) in Guernsey, Tuscarawas, and Muskingum counties, this sandstone has produced in excess of 750,000 barrels of oil. The main gas pools are in Ashtabula County in the northeastern corner of the state and in Guernsey, Coshocton, southern Tuscarawas, and Muskingum counties in the central part. In general, Oriskany wells have large initial open-flow volumes and high rock pressures, but are short-lived. The rocks of this zone also yield flowing water wells; therefore, the oil and gas in the Oriskany are found in areas with structural relief.

## PRODUCING AREAS

Calvert (1964) listed 53 named oil and gas pools that are either mostly or wholly in Washington County. Figure 38 generalizes the principal oil- and gas-producing areas for the county. This figure is based on well concentrations shown on the Division of Geological Survey's township property maps and may differ in detail from Calvert's (1964) map. No attempt has been made to suggest trends not supported by well data. Field names have not been used because many of the named pools are portions of larger producing areas.

Production in Washington County is divided almost equally between rocks of Pennsylvanian and Mississippian ages, with one occurrence in the Devonian. There are more individual producing sands in the Pennsylvanian than in the Mississippian, but Mississippian zones tend to be productive over a wider geographic area. In the county there are, for example, 62 occurrences of oil and gas production from about 10 different Pennsylvanian sands, whereas only 4 Mississippian sands account for 64 occurrences. Most fields in Washington County were developed in more than one zone.

## CONDITIONS OF ACCUMULATION

There has been some disagreement among workers on the relationship of structure and stratigraphy to oil and gas accumulation in eastern Ohio. Cottingham (1927, p. 945) thought structure was important:

> The majority of the producing fields of eastern Ohio display some relationship to structure, although the relationship is ideal in but few cases.

Pepper and others (1947) stated:

> The location of oil and gas pools in the First Berea sand appears to be controlled largely by local differences in permeability and porosity of the sand. . . . Apparently structure also exerts some control on the localization and accumulation of gas in the southeastern Ohio part of the map.

An examination of the Berea sand structure map (pl. 11) shows that, although many successful wells have been drilled on structure, there has been production from wells drilled in areas with no obvious structure. Lockett (1947, p. 1026) summed up the situation:

> Many of these structures have been proved to be the controlling factors in shallow sand accumulation, although as many more which looked as promising when mapped have been dry. Owing to the lack of systematic and connected work in any considerable area, the controlling influence of two major structural features has not been recognized.

The authors are of the opinion that structure is an influencing factor, but does not necessarily play the paramount role in eastern Ohio in the accumulation of oil and gas. Stratigraphic traps seem to be of equal if not greater importance in Washington County.

Even though many oil and gas accumulations are stratigraphic in nature, data on porosity and permeability are extremely sparse for most sands in the Washington County area. The available information from both core analyses and nuclear log interpretations is summarized in tables 12 and 13.

TABLE 12.—*Porosity and permeability data from core analyses of oil and gas sands in Washington County, Ohio*[1]

| Township | Permit no. | Lease name and no. | Location | Depth (ft) | Porosity (%) | Oil saturation (%) | Water saturation (%) | Oil yield (bbls/acre-ft) | Average permeability (millidarcys) | Sand |
|---|---|---|---|---|---|---|---|---|---|---|
| Wesley | 147 | Burns #1 | Lot 1144, sec. 33N | 506-509.3 | 16.8 | 15.4 | 54.5 | 215 | 63.0 | "Cow Run" |
| | | | | 512.3-519.6 | 23.8 | 16.6 | 55.6 | 285 | 1770.0 | "Cow Run" |
| | | | | 519.6-521.3 | 7.9 | 8.1 | 58.7 | 123 | 0.9 | "Cow Run" |
| | 148 | Bowman #1 | Lot 1124, sec. 27N | 328-342.7 | 13.7 | 23.2 | 53.7 | 247 | 5.7 | "Peeker" |
| | | | | 377-385.5 | 18.4 | 21.6 | 56.3 | 309 | 136.5 | "Cow Run" |
| | 146 | Bowman #1 | Lot 1142, sec. 33N | 183-189 | 16.5 | 8.4 | 63.6 | 109 | 6.4 | "Wolf Run" |
| | | | | 286.5-291.5 | 13.7 | 22.6 | 64.3 | 237 | 1.4 | "Cow Run" |
| | | | | 293-307 | 19.8 | 22.3 | 61.6 | 335 | 607.0 | "Cow Run" |
| Ludlow | 2972[2] | Day *et al.* #1 | SW¼ sec. 27 | 1586-1603 | 12.0 | 0.9 | 90.0 | 6 | 0.4 | "Keener" |
| | | | | 1607-1694 | 6.3 | ND[3] | ND | ND | 0.4 | "Big Injun" |
| | | | | 1700-1750 | 7.7 | 5.6 | 67.0 | 36 | 0.4 | "Big Injun" |
| | | | | | | | | | | "Squaw" |

[1] All data from Ohio Division of Geological Survey files unless otherwise indicated.
[2] Whieldon and Evans (1966).
[3] Not determined; this value determined only on effective interval.

TABLE 13.–*Porosity data from nuclear logs of oil and gas sands in Washington County, Ohio*

| Township | Permit no. | Lease name and well no. | Location | Depth (ft) | Porosity (%) | Gas saturation (%) | Oil saturation (%) | Water saturation (%) | Hydrogen index | Formation or sand |
|---|---|---|---|---|---|---|---|---|---|---|
| Barlow | 2780 | McCoy #1A | NW¼ sec. 6 | 1868-1872 | 16.5 | 75 | | | 4.5 | Berea |
| Barlow | 3027 | Callihan #1 | NE¼ sec. 1 | 2043-2050 | 17.5 | 78 | | | 4.5 | Berea |
| Belpre | 3000 | Mulligan #1 | NE¼ sec. 27E | 1912-1918 | 18.5 | 75 | | | 5.0 | Berea |
| Belpre | 3011 | Mulligan #2 | NE¼ sec. 27E | 1886-1892 | 18.5 | 76 | | | 4.5 | Berea |
| Belpre | 3058 | Mulligan Sr. *et al.* #2 | NW¼ sec. 21E | 1886-1892 | 17.5 | 75 | | | 4.5 | Berea |
| Dunham | 385 | Needham #1 | NW¼ sec. 11 | 1787-1793 | 16.0 | 75 | | | 4.5 | Berea |
| Dunham | 2985 | Campbell #1 | SE¼ sec. 28E | 1873-1878 | 14.5 | 70 | | | 4.5 | Berea |
| Dunham | 3001 | Weaver #1 | SW¼ sec. 28E | 2002-2006 | 14.0 | 50 | | | 7.0 | |
| | | | | 2099-2104 | 15.5 | 72 | | | 4.5 | Berea |
| Dunham | 3018 | Hinton #1 | NE¼ sec. 36 | 2012-2019 | 15.7 | 72 | | | 4.5 | Berea |
| Dunham | 3030 | Hively #1 | NW¼ sec. 29E | 2048-2056 | 18.5 | 77 | | | 4.5 | Berea |
| Dunham | 3034 | Burrows Heirs #1 | SE¼ sec. 28E | 1885-1891 | 16.5 | 74 | | | 4.5 | Berea |
| Dunham | 3039 | Grimm #1 | NE¼ sec. 5 | 1840-1844 | 18.5 | 76 | | | 4.5 | Berea |
| Dunham | 3040 | Constitution Stone #1 | SW¼ sec. 36 | 1910-1918 | 15.0 | 10 | | | 14.0 | Berea |
| Dunham | 3062 | Dalton #1 | NE¼ sec. 11 | 1814-1822 | 15.5 | 72 | | | 4.5 | Berea |
| Warren | 2880 | Lee #2 | SW¼ sec. 16 | 1190-1194 | 20.0 | 50 | | 50 | | |
| | | | | 1220-1226 | 17.0 | 35 | 35 | 30 | | "Macksburg 500" |
| | | | | 1226-1233 | 18.5 | 38 | 30 | 32 | | "Macksburg 500" |
| Warren | 2892 | Eddy #1 | NE¼ sec. 16 | 2088-2093 | 11.0 | 10 | 72 | 18 | | Berea |
| | | | | 2093-2096 | 9.5 | 42 | 37 | 21 | | Berea |
| Warren | 2899 | Pottmeyer #1 | SW¼ sec. 17 | 2080-2083 | 13.0 | 30 | 50 | 15 | 10.5 | Berea |
| | | | | 2083-2084 | 13.0 | | 80 | 20 | 15.0 | Berea |
| | | | | 2084-2088 | 11.5 | 20 | 62 | 18 | 11.0 | Berea |
| Warren | 3003 | Fordham #1 | NE¼ sec. 25 | 2067-2070 | 16.0 | 45 | | | 9.0 | Berea |
| | | | | 2070-2076 | 15.0 | 10 | | | 14.0 | Berea |
| Warren | 3017 | Constitution Stone #5 | Lot 271 | 2086-2092 | 17.5 | 75 | | | 4.5 | Berea |
| Warren | 3037 | Musgrave #1 | SW¼ sec. 31 | 1883-1890 | 15.0 | 30 | | | 12.0 | Berea |
| Warren | 3042 | Weaver #2 | NW¼ sec. 19 | 2117-2126 | 17.5 | 75 | | | 4.5 | Berea |
| Warren | 3043 | Goodwin #2 | NW¼ sec. 19 | 2012-2018 | 15.0 | 35 | | | 10.0 | Berea |

## SECONDARY RECOVERY

Although secondary recovery methods were tried in Washington County as early as 1903, very few data are available on this aspect of the petroleum industry. Cashell (1949, p. 297) stated:

> The first known attempt to increase oil production by repressuring an oil sand in Ohio was made in the Macksburg pool by I. L. Dunn in 1903. The original venture consisted of injecting gas into an oil well for a period of ten days at 45 psi pressure. At the conclusion of this injection period pressure was released and the well put to pumping. Increased production resulted until the injection gas had been dissipated from the formation. This procedure was later patented as the Smith-Dunn process.

Lewis (1917, p. 36) gave a comprehensive discussion of the Smith-Dunn process, and stated:

> The process is known to have been employed on over 90 properties, of which at least 80 per cent have been successful. Nearly all of these properties are located in the Appalachian fields in the southeastern parts of Ohio and the northwestern parts of West Virginia.

Repressuring has been tried in southeastern Ohio in most sands from the Berea to the Mitchell, and, according to Lewis, the Smith-Dunn process was most successful in the "First Cow Run" in southeastern Ohio and in the "Big Lime" sand near Woodsfield, Monroe County, Ohio.

The exact number of secondary recovery operations that have been attempted in the county is not known. Repressuring with air or gas was tried in many areas of the county prior to the regulation that a permit to use secondary recovery methods was required. Public records, therefore, do not exist for all secondary recovery units. Table 14 lists the more recent known (as of 1968) secondary efforts without regard to their current operating status.

The following brief history has been compiled for the "Big Injun" pilot waterflood attempted in secs. 14 and 15 of Independence Township. The authors are indebted to Carl Heinrich (personal communication) of Marietta for these data. A pilot flood was conducted in this area on the Thomas lease from 1955 to 1958. The bottom 8 to 10 feet of the "Big Injun" sand was flooded in this test. Core analysis of the sand indicated a porosity range of 9.0 to 22.8 percent, permeability of 10.5 to 43.0 millidarcys, and a residual oil saturation of 8,000 barrels per acre. Four old wells (#2, #3, #8, and #9) on the lease were prepared for input by cleaning out, logging, and plugging back to the bottom of the pay. Tubing was cemented as far as the top of the pay. A new well (#12) was drilled in the center of the pattern. This well was cored, logged, and fractured with 750 gallons of oil and 1,000 pounds of sand at a breakdown pressure of 1,500 psi. Injection pressure was from 600 to 900 psi. Daily injection rates averaged 10 to 15 barrels of water per well. From 1955 to February 1958 a total of 61,822 barrels of water was injected, with wells #2, #3, #8, and #9 receiving 19,605, 13,960, 8,959, and 19,298 barrels, respectively.

TABLE 14.—*Secondary recovery operations in Washington County, Ohio (present status unknown)*

| Township | Location | Company | Sand | Method |
|---|---|---|---|---|
| Aurelius | Sec. 7 | Ayrshire Oil Corp. (formerly Super Steam) | "Buell Run" | Waterflood |
| Aurelius | Sec. 29 | Juniper Oil & Gas Co. | "Buell Run" | Waterflood |
| Independence | Secs. 14, 15 | Baron Kidd (formerly Tennessee Producing) | "Big Injun" | Waterflood |
| Liberty | Secs. 23, 29 | Baron Kidd (formerly Tennessee Producing) | "Second Cow Run" | Waterflood |
| Marietta | Secs. 10, 16 | Petrotherm, Inc. | "Mitchell" | Waterflood |
| Newport | Secs. 31E, 35E | David F. Edgar *et al.* | "Mitchell" | Gas injection |
| Palmer | Sec. 31 | Waverly Oil Works Co. | "Cow Run" | Waterflood |
| Wesley | Sec. 27 | Quaker State Engineering Co. | "Wolf Creek" | Waterflood |
| Wesley | Sec. 33 | Dawson Oil Co. | "Cow Run" | Air injection |

No definite production figures are available for the individual wells; however, well #12 was reported to have had a production increase of 300 percent during 1957. Increases have been noticed in wells adjacent to the flood area several years after termination of the project. The increase in average daily production of the following three wells reflects the effect of the pilot well on the adjacent area:

| *Well* | *1954* | *1966* |
|---|---|---|
| Thomas #10 | 0.10 bbl | 1 bbl |
| Hollstein #3 | 0.50 bbl | 2 bbl |
| Yost #6 | 0.46 bbl | 0.86 bbl |

This project seems to have been unsuccessful, but the difficulties may have been mainly mechanical and operational. The equipment was old, salvaged from other leases and subject to frequent breakdowns. The water came from a shallow well and was not filtered continuously during injection. The project was discontinued following a fire which destroyed the plant.

Interest in secondary oil recovery has resulted in investigations by the U.S. Bureau of Mines. However, Wasson (1967), reporting on one such study in Newport Township, stated:

> The results of the study indicate that there is insufficient oil in places to form an oilbank in either the western Mitchell pool or the Berea sand, and that no commercial recovery of oil by waterflooding can be obtained in these reservoirs.

TABLE 15.—*Characteristics of crude oil*

| Township | Permit no. | Lease name and well no. | Location | Producing zone | Lab no.[1] | Crude oil: Color | Crude oil: Gravity API at 60°F | Crude oil: Viscosity at 100°F |
|---|---|---|---|---|---|---|---|---|
| Adams | 2531 | Pottmeyer #1 | Lot 26, Cats Creek Allotment | Berea | 1466 | 4½ (1 dil)[3] | 34.1 | |
| Adams | 2535 | Shantz #1 | Lot 16, Cats Creek Allotment | Berea | 1429 | 8 (0 dil) | 38.6 | |
| Adams | 2679 | Huck #1 | Lot 12, Rainbow Creek Allotment | Berea | 1625 | 5 (1 dil) | 39.7 | |
| Barlow | 249 | Jones #1 | Sec. 20 | Berea? | 360 | 5 (2 dil) | 53.3 | 31.2 |
| Barlow | 612-2 | Foreman #2 | Sec. 17 | "2nd Cow Run" | 655 | 4½ (2 dil) | 24.3 | |
| Belpre | 1515 | Houser #1 | Sec. 8 | Oriskany | 583 | 7 | 39.8 | 46.0 |
| Decatur[4] | 819 | Dolus #1 | Sec. 6 | "Peeker" | 468 | 6 (1 dil) | 37.3 | 52.8 |
| Dunham | 2998 | Koon #1 | Sec. 29E | Berea | 2066 | 4½ (1 dil) | 39.4 | |
| Dunham | 3029 | Haythorn #1 | Sec. 29E | Berea | 2187 | 5 (1 dil) | 39.7 | |
| Fairfield[4] | 670A-1 or 670A-2[5] | Walsh | Sec. 1 | "Cow Run" | 169 | 4½ (2 dil) | 52.1 | 34.6 |
| Fairfield | 2172 | Remely #2 | Sec. 18 | "Big Injun" | 803 | 4 (2 dil) | 36.8 | 56.4 |
| Fearing | 2400 | Seyler #1 | Lot 104 | "Buell Run"? | | 4 (2 dil) | 41.6 | |
| Ludlow | 1314-2 | Hall #2 | Sec. 28 | Ohio Shale | 2858 | 7 (0 dil) | 44.2 | |
| Ludlow | 3184 | West #1 | Sec. 28 | "Gordon" | 2708 | 5 (0 dil) | 45.8 | |
| Muskingum | 2577 | Decker #1 | Lot 14, Rainbow Allotment | Berea | 1468 | 4 (1 dil) | 36.5 | |
| Warren | 2831 | Wynn #3 | Sec. 16 | Berea | 1704 | 4 (1 dil) | 37.7 | |
| Warren | 2870 | Wynn #1 | Sec. 16 | Berea | 1703 | 4½ (1 dil) | 37.3 | |
| Warren | 2994 | Nichols #1 | Sec. 25 | Berea | 2191 | 3½ (1 dil) | 40.5 | |
| Warren | 3209 | Lane #1 | Sec. 18 | Berea | 2752 | 6 (1 dil) | 36.8 | |
| Watertown | 2694 | Arnold #1 | Lot 12, South Branch Allotment | Berea | 1586 | 7 (1 dil) | 39.3 | |
| Watertown | 2811 | Ford #1 | Lot 20, South Branch Allotment | Berea | 1523 | 7 (1 dil) | 37.4 | |
| Watertown | 2858 | Gearhart #1 | Lot 825 | "Peeker" | 1532 | 6 (1 dil) | 45.0 | |
| Wesley | 1580 | Berg #1 | Sec. 24 | | 586 | 5 (2 dil) | 46.5 | 33.8 |

[1] All analyses furnished courtesy of Dr. E. E. Smith of the Engineering Experiment Station, The Ohio State University.
[2] Saybolt universal viscosity.
[3] Dilution of 15 percent in water-white naphtha.
[4] Analyses also published in Ohio State University Engineering Experiment Station Bulletin 138, 1949.
[5] Specific permit number could not be determined; more than one well on property.

## CHARACTERISTICS OF WASHINGTON COUNTY CRUDE OIL

Analyses of 17 samples of crude oil and 1 of gas are available for the county. Twelve of the oil samples are assigned to Corning grade, three to Zanesville, and only two to Buckeye-Pennsylvania. Table 15 lists the characteristics of these 17 samples and table 16 presents chemical data for the single gas sample.

## BRINE

Man's desire for salt is one of his strongest creature needs and the search for and production of salt has always ranked high in our endeavors. The early settlers in Ohio and in Washington County were no exception, and considerable effort was devoted to the search for natural brines which could be evaporated.

Naturally occurring brines, as opposed to rock salt, can be found at depth in almost all parts of the county. Brine wells were being drilled in adjacent counties as early as 1814; however, no major salt-evaporating plants were ever established in Washington County. Hildreth (1826, p. 4-5) gave an excellent account of activities around 1819 in the search for brine in Washington and adjacent counties. A portion of Hildreth's observations are as follows:

> Two attempts at boring for salt water have been made in the county. The first was made two or three years since, about 40 miles from Marietta, near the Muskingum river; they proceeded to the depth of about 200 feet, and, their prospects of obtaining water rather diminishing than increasing, they gave up the work. The other trial is now being made on the waters of Little Muskingum creek, about 12 miles from Marietta.

Speaking of the second well, Hildreth continued:

> There is a continual discharge of carbonated hydrogen gas from the well; and also from the bed of the creek on which the well is situated, at various places, for a distance of half a mile . . . . It was this discharge of gas that induced the present proprietors to search for salt water, it being invariably found to accompany all the salt water, of any consequence, that has been discovered in this western county . . . . It is this discharge of gas that brings the salt water from such vast depths in the bowels of the earth, to the surface. And where water has been discovered, and the supply of gas has failed, the water immediately sunk in the well, and could not, by any means used, be brought to the top of the well.

Specific data on brine reserves are largely lacking, although the quantity of available brine is almost certainly exceedingly large. However, the future potential for exploitation of natural brines in Washington County is probably not great; salt manufactured from natural brines has been almost completely replaced in Ohio by the production of rock salt by underground and solution mining. Reserves of rock salt in the eastern portion of the county would probably make uneconomic establishment of a salt industry based on natural brines. The greatest potential for natural brines would be for production of

*samples from Washington County, Ohio*

| Residue after distillation | | | | Viscosity index | Conradson carbon residue | Fire point (°F) | Flash point (°F) | Fractions (%) | | | | | | Grade |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| % by weight | API at 60°F | Viscosity[2] at 100°F | Viscosity[2] at 210°F | | | | | Gasoline | Kerosene | Oil | Wax distillate | Residue by volume | Loss | |
| 50 | 24.8 | 2725 | 150 | 89 | 2.18 | | | 14 | 17 | 12 | 12 | 45 | 0 | Corning |
| 45 | 24.6 | 2726 | 150 | 89 | 2.3 | | | 27 | 14 | 10 | 9 | 40 | 0 | Corning |
| 46 | 24.7 | 2740 | 750 | 88 | 2.26 | | | 27 | 14 | 9 | 9 | 41 | 0 | Corning |
| 10.2 | 24 | | | | 5.32 | 545 | 475 | | | | | 8.5 | | Corning |
| 21.6 | 24.3 | 2400 | 150 | 98 | 4.23 | 580 | 530 | 33 | 14 | 13 | 20 | 19 | 1 | Corning |
| 26.5 | 26.6 | 2100 | 148.5 | 105 | 1.64 | 625 | 565 | 25 | 12 | 13 | 25 | 24 | 0 | Buckeye-Pennsylvania |
| 29.2 | 26 | 2197 | 143.9 | 99.5 | 2.30 | 600 | 550 | 18 | 17 | 15 | 23 | 26 | 1 | Buckeye-Pennsylvania |
| 39 | | 2580 | 150 | 93 | 3.2 | | | 32 | 16 | 11 | 6 | 35 | 0 | Corning |
| 38 | 24.6 | 2620 | 150 | 92 | 2.50 | | | 26 | 16 | 12 | 12 | 34 | 0 | Corning |
| 10.1 | 24.8 | | | | 4.95 | 545 | 510 | 51 | 30 | 9 | 9 | 9 | 2 | Corning |
| 42.2 | 24.2 | 2520 | 150.8 | 96 | 3.45 | | | 26 | 12 | 9 | 12 | 39 | 2 | Zanesville |
| 24 | 25.4 | 2350 | 150 | 100 | 3.25 | | | 29 | 16 | 12 | 22 | 21 | 0 | Zanesville |
| 30 | 26.5 | 2400 | 150 | 98 | 2.05 | | | | | | | | | Corning |
| 23 | 26.6 | 2360 | 150 | 99 | 1.80 | | | 40 | 14 | 12 | 13 | 21 | 0 | Buckeye-Pennsylvania |
| 45 | 25.4 | 2620 | 150 | 92 | 1.92 | 565 | 515 | 23 | 15 | 11 | 11 | 40 | 0 | Corning |
| 45 | 25.1 | 2510 | 150 | 95 | 2.42 | | | 25 | 12 | 10 | 12 | 41 | 0 | Corning |
| 45 | 25.1 | 2470 | 150 | 96 | 2.12 | | | 24 | 13 | 10 | 12 | 41 | 0 | Corning |
| 36 | 25.3 | 2620 | 150 | 92 | 1.45 | | | 30 | 16 | 12 | 10 | 32 | 0 | Corning |
| 43 | 25.1 | 2510 | 150 | 95 | 2.16 | | | 25 | 16 | 13 | 7 | 39 | 0 | Corning |
| 47 | 24.8 | 3016 | 150 | 81 | 2.7 | | | 25 | 13 | 9 | 11 | 42 | 0 | Corning |
| 44 | 24.6 | 2760 | 150 | 88 | 2.5 | | | 27 | 12 | 9 | 13 | 39 | 0 | Corning |
| 17.5 | 25.0 | 2440 | 150 | 97 | 3.22 | | | 32 | 20 | 14 | 18 | 16 | 0 | Zanesville |
| 10.2 | 24.7 | 2480 | 150 | 96 | 6.03 | 595 | 525 | 43 | 19 | 12 | 13 | 9 | 4 | Corning |

TABLE 16.—*Natural gas analysis*[1] *from Washington County, Ohio*

| Component | Molecular percent | Component | Molecular percent |
|---|---|---|---|
| Methane | 82.6 | Nitrogen | 1.6 |
| Ethane | 10.0 | Oxygen | 0.0 |
| Propane | 4.0 | Argon | 0.0 |
| N-butane | 1.1 | Helium | 0.1 |
| Isobutane | 0.1 | Hydrogen | 0.0 |
| N-pentane | 0.2 | Hydrogen sulfide | 0.0 |
| Isopentane | 0.1 | Carbon dioxide | trace |
| Cyclopentane | 0.1 | Heating value[2] | 1,182 |
| Hexanes plus | 0.1 | | |

[1] Haas #1, lot 72, Bear Creek Allotment, Adams Twp.; permit no. 2760; U.S. Bur. Mines lab. no. 9052; sample produced from Berea Sandstone; wellhead pressure 735 psi; open flow 960 MCF/day.
[2] Calculated gross Btu/cu ft, dry, at 60° F and 30 in Hg.

products such as bromine or magnesium if brines with sufficient concentrations of these elements could be found. Only three brine analyses (reproduced below) are available for the county; none of them indicate sufficiently high concentration of compounds other than sodium chloride to warrant exploitation.

Barlow Township, NE¼ sec. 24, James H. McIntire #1, Permit 2756. "First Salt Sand" of drillers, depth 930-942 feet; T.D. 1176 feet. Sampled by B. E. Smith; cable tool bailer, lab. no. T-16760. Analysis courtesy of Pan American Petroleum Corporation.

| *Ion* | *mg/l* | *meq/l* |
|---|---|---|
| Na | 22,774 | 990.66 |
| Ca | 4,900 | 244.51 |
| Mg | 1,320 | 108.50 |
| Fe | | |
| $SO_4$ | 120 | 2.50 |
| Cl | 47,500 | 1,339.50 |
| $CO_3$ | 0 | |
| $HCO_3$ | 102 | 1.67 |
| $H_2S$ | | |
| I | 0 | |
| Br | 233 | 2.92 |

| | |
|---|---|
| Total solids as a summation of ions (mg/l) | 76,716 |
| Total solids by evaporation and ignition of residue at low red heat (mg/l) | 81,520 |
| Resistivity (ohms/$M^2M$ at 77°F) | 0.093 |
| pH | 6.3 |
| Specific gravity (60°/60°F) | 1.058 |
| Total cations (meq/l) | 1344 |
| Total anions (meq/l) | 1347 |

Dunham Township, NW¼ sec. 16, B. O. and Darrell Ross #1, Permit 2821. "Big Injun" of drillers, depth 1241-1357 feet; T.D. 1806 feet. Sampled by B. E. Smith; cable tool bailer, lab. no. T-016761. Analysis courtesy of Pan American Petroleum Corporation.

| *Ion* | *mg/l* | *meq/l* |
|---|---|---|
| Na | 20,968 | 912.04 |
| Ca | 3,360 | 167.66 |
| Mg | 990 | 81.38 |
| Fe | | |
| $SO_4$ | 95 | 1.98 |
| Cl | 41,100 | 1,159.02 |
| $CO_3$ | | |
| $HCO_3$ | 5 | 0.08 |
| $H_2S$ | | |
| I | 0 | |
| Br | 215 | 2.69 |

| | |
|---|---|
| Total solids as a summation of ions (mg/l) | 66,518 |
| Total solids by evaporation and ignition of residue at low red heat (mg/l) | 71,960 |
| Resistivity (ohms/$M^2M$ at 77°F) | 0.101 |
| pH | 4.8 |
| Specific gravity (60°/60°F) | 1.049 |
| Total cations (meq/l) | 1162 |
| Total anions (meq/l) | 1164 |

Newport Township, NW¼ sec. 21E, Barber Riggs and Willard Schneider #1, Permit 2824. "Big Injun" of drillers, depth unknown; T.D. 1425 feet. Sampled by B. E. Smith, cable tool bailer, lab. no. T-16762. Analysis courtesy of Pan American Petroleum Corporation.

| *Ion* | *mg/l* | *meq/l* |
|---|---|---|
| Na | 35,073 | 1,525.61 |
| Ca | 11,000 | 548.90 |
| Mg | 1,660 | 136.45 |
| Fe | | |
| $SO_4$ | | |
| Cl | 78,400 | 2,210.88 |
| $CO_3$ | | |
| $HCO_3$ | 5 | 0.08 |
| $H_2S$ | | |
| I | 7.2 | 0.06 |
| Br | 692 | 8.66 |

| | |
|---|---|
| Total solids as a summation of ions (mg/l) | 126,138 |
| Total solids by evaporation and ignition of residue at low red heat (mg/l) | 133,520 |
| Resistivity (ohms/$M^2M$ at 77°F) | 0.064 |
| pH | 4.7 |
| Specific gravity (60°/60°F) | 1.092 |
| Total cations (meq/l) | 2211 |
| Total anions (meq/l) | 2220 |

## ROCK SALT

Bedded rock salt of Cayugan (Silurian) age probably underlies all or most of Grandview, Independence, and Ludlow Townships. There is a strong possibility that easternmost Lawrence, Liberty, and Newport Townships also are underlain by rock salt (fig. 39).

It is difficult to define closely the distribution and thickness of Silurian salt in this area because of the scarcity of wells and cores of sufficient depth to penetrate the salt-bearing sequence. Only a few wells in Washington County, a core in Jackson Township, Monroe County, and several wells on the West Virginia side of the Ohio River have gone to or through the position of the salt. Table 17 lists the pertinent data for each of the information points available.

These data suggest a thickness (fig. 39) of slightly over 100 feet in the eastern half of Grandview Township, from 50 to 100 feet in western Grandview, most of Independence and Ludlow, and the eastern tip of Newport Townships, and from 0 to 50 feet in the eastern half of Lawrence, Liberty, and Newport Townships. These thicknesses do not represent pure salt; the sequence is broken by thin lenses of dolomite, limestone, and anhydrite. The salt itself, however, is of relatively high purity.

Haught (1956, p. 30), in his discussion of the stratigraphy of the Sandhill deep well in Wood County, West Virginia, stated that

> the Cayugan is 730 feet thick, and consists mainly of dolomite, with relatively little anhydrite, and no salt, as was to be expected. It seems clear that the Burning Springs anticline is the western boundary of the upper Silurian salt beds in this vicinity.

The authors agree with Haught, and the western salt

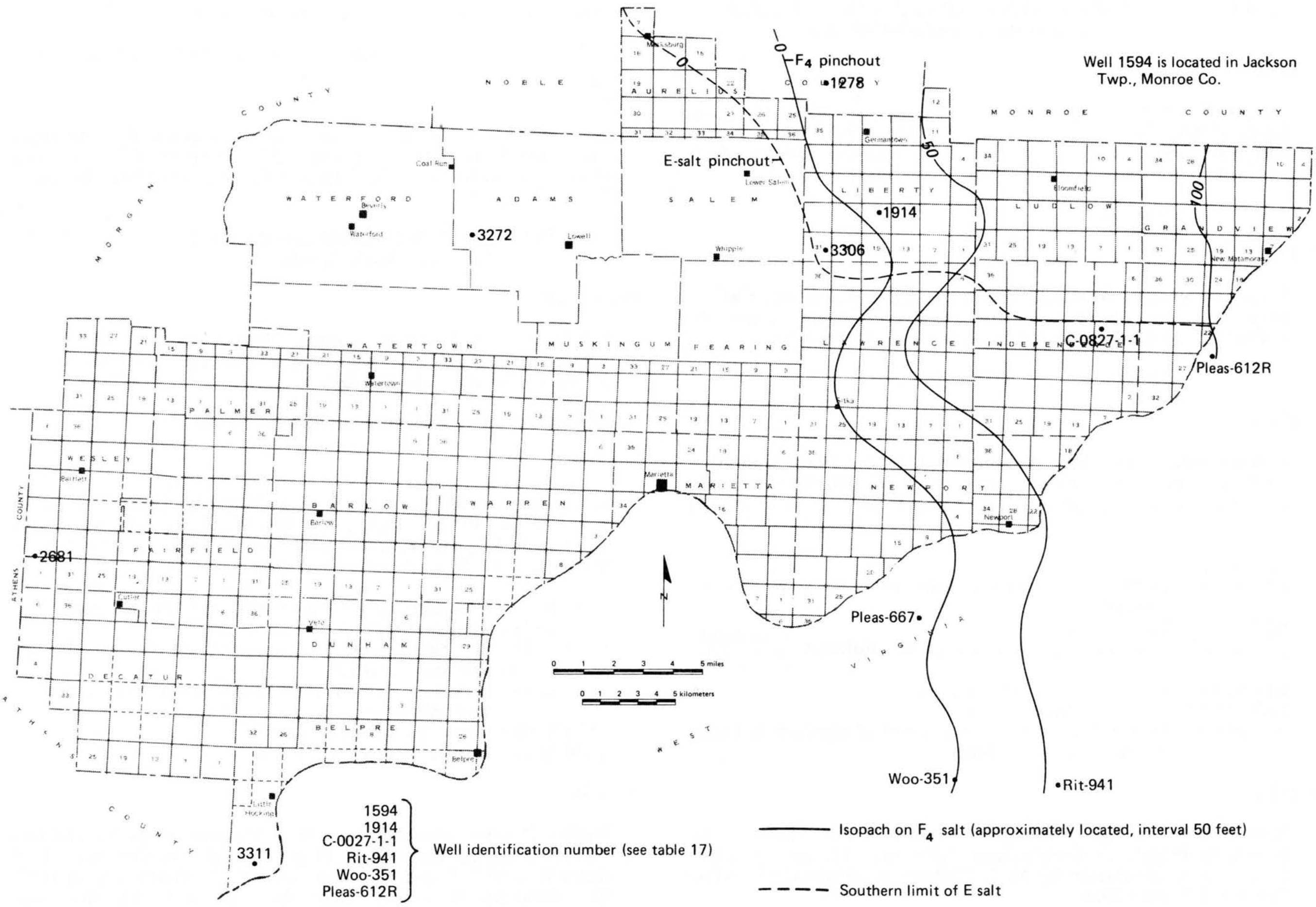



FIGURE 39.—Generalized distribution and estimated thickness of rock salt in Washington County, Ohio.

boundary in Washington County has been drawn more or less along the northward extension of the Burning Springs anticline. Both the Scott well (P-1914), in sec. 20, Liberty Township, and the Wood County deep well (Woo 351) are located on or near the axial trend of the Burning Springs anticline; no salt was recorded in either well.

The top of the salt in eastern Washington and southeastern Monroe County and adjacent areas of West Virginia strikes approximately N. 23° E. and dips S. 67° E. at 89 feet per mile. Salt is present at depths of 5,269 feet below sea level in sec. 10, Independence Township, and about 5,580 feet below sea level at the Ohio River in sec. 27, Grandview Township. Pepper (1947, p. 230) indicated that there is considerable variation in the stratigraphic level of the uppermost salt beds in widely spaced wells, but that there is generally good agreement between adjacent wells. It would appear that the uppermost salt bed in this immediate area is stratigraphically equivalent to the $F_4$ salt of Michigan (Michael J. Clifford, personal communication, 1970) and is the same unit in each of the few wells for which data are available. Data developed by Clifford (1973) indicate that the E salt of Michigan may be present on the order of 380 feet below the base of the $F_4$ salt in all or parts of Grandview, Independence, Ludlow, Liberty, and Aurelius Townships. Thicknesses of as much as 50 feet are postulated for the lower salt.

This sequence of salt beds represents a real economic potential for easternmost Washington County. An indication of the large tonnages of salt which are potentially available in eastern Washington County can be seen from the following computation. An acre-foot of pure rock salt contains approximately 2,963 tons; thus an acre of salt 100 feet thick would yield 296,300 tons, and a square mile of salt of that thickness would equal about 189,632,000 tons. There is undoubtedly sufficient rock salt in the county to provide a substantial industrial base. Salt is used by the chemical industry as a raw material in production of caustic soda (sodium hydroxide), chlorine, and soda ash (anhydrous sodium carbonate). These chemicals are used in turn in the manufacture of such items as glass, laundry bleach, soap, and numerous chemicals. Salt in its natural state is used for seasoning, for ice and snow control, in food processing, and for livestock. At a number of places along the Ohio River, bedded rock salt has for many years been mined for chemical uses by brining. As the demand for chemicals produced from salt and for other by-products increases, the relatively thick deposits of the county could be brought into production.

TABLE 17.—*Wells and cores penetrating Silurian rock salt in eastern Washington County and adjacent areas*

P-3272

Adams Township, Washington County, Ohio. Offenberger #1, Berry Holding Company, Lot 29, allotment between Rainbow and Waterford, elevation 947 feet. Log interpretation by M. J. Clifford; geophysical logs, Ohio Div. Geol. Survey files.

No salt

P-3311

Belpre Township, Washington County, Ohio. Lamp #1, Carl E. Smith, Inc., Lot 66, elevation 619 feet. Log interpretation by M. J. Clifford; geophysical logs, Ohio Div. Geol. Survey files.

No salt

C-0027-1-1

Independence Township, Washington County, Ohio. Knowlton #1-B, Sylvania Producing Company, NW¼ sec. 10, elevation 1001 feet. Sample description by M. C. Kiess; Ohio Div. Geol. Survey files.

*Depth (ft)*
6260-6270 - Light-brown dolomitic lime; probably some salt but washed out
6270-6310 - Pure rock salt
6310-6340 - Salt; small amount of brown dolomitic lime } probably $F_4$ salt
6340-6352 - Light-brown dolomitic lime
6352-6370 - Dolomite, 50%; salt, 50%
6370-6400 - Brown dolomite; small amount of argillaceous finely granular dark-gray lime

P-3310

Lawrence Township, Washington County, Ohio. Matheny #2, Guernsey Petroleum Corporation, NE¼ sec. 15, elevation 640 feet. Log interpretation by M. J. Clifford; geophysical logs, Ohio Div. Geol. Survey files.

5525-5563 - Salt
5563-5580 - Probably anhydrite } $F_4$ salt
5580-5606 - Salt

P-1914

Liberty Township, Washington County, Ohio. Scott #1, Great Lakes Carbon Company, NE¼ sec. 20, elevation 904 feet. Sample description by G. G. Shearrow; Ohio Div. Geol. Survey files.

No salt recorded; probably washed out

P-3306

Liberty Township, Washington County, Ohio. Gebike #1A, Eastern Operating Company, SE¼ sec. 31, elevation 889 feet. Log interpretation by M. J. Clifford; geophysical logs, Ohio Div. Geol. Survey files.

5816-5854 - Salt with several probable anhydrite beds (est. 21 ft of total interval is salt). E salt

P-2681

Wesley Township, Washington County, Ohio. Pahl #1, Atlas Exploration Company, SW¼ sec. 2, elevation 960 feet. Log interpretation by M. J. Clifford; geophysical logs, Ohio Div. Geol. Survey files.

No salt

P-1594

Jackson Township, Monroe County, Ohio. ARA salt test well #1, Area Redevelopment Administration, NW¼ sec. 18, elevation 648 feet. Gamma ray-neutron log, Ohio Div. Geol. Survey files.

6575-6700 - Salt with stringers of dolomite and anhydrite. $F_4$ salt

P-1278

Elk Township, Noble County, Ohio. Ullman #1, Amerada Petroleum Corporation, SE¼ sec. 31, elevation 1035 feet. Log interpretation by M. J. Clifford; geophysical logs, Ohio Div. Geol. Survey files.

5508-5530 - Salt with probable anhydrite beds (est. 18 ft of total interval is salt). $F_4$ salt

Pleas-612R

Union District, Pleasants County, West Virginia. Benjamin #5, FMC Corporation, 3.02 miles S of 39°30′ and 0.68 mile west of 81°05′, elevation 711 feet; drillers' record.

6388-6484 - Salt, dolomite, anhydrite. $F_4$ salt

Rit-941

Grant District, Ritchie County, West Virginia. Rinehart #1, 4.51 miles S of 39°20′ and 1.2 miles W of 81°10′, St. Marys quadrangle SW, elevation 830 feet. Sample description by J. H. C. Martens; v. 17, West Virginia Geol. Survey.

6498-6523 - Dolomite; anhydrite, brown, very fine-textured
6523-6528 - Salt, nearly pure
6528-6575 - Salt, with some dolomite and anhydrite } $F_4$ salt
6575-6588 - Salt and anhydrite
6588-6598 - Dolomite, brown, very fine textured; with some salt and anhydrite
6598-6606 - Lime (from drillers' record)
6606-6621 - Salt (from drillers' record)

Woo-351

Walker District, Wood County, West Virginia. Hope Natural Gas #9634, (Sandhill deep well), Hope Natural Gas Company, 1.14 miles W of 81°15′ and 5.4 miles S of 39°21′, Marietta quadrangle SE, elevation 1039 feet; Rept. Inv. 14, West Virginia Geol. Survey.

No salt recorded

## SANDSTONE

Sandstone is known to have been quarried commercially in Washington County for use as decorative and building stone as well as for grindstones since as early as 1819 (Hildreth, 1826). Hildreth specifically mentioned grindstones as

> quite an article of commerce; and hundreds of excellent grindstones are every year sent down the Ohio.

Grindstones have been quarried through the years at numerous localities around the county; however, production was centered in Warren, Dunham, and Barlow Townships, primarily along the Ohio River and the then-existing railroads. Small quarries were quite numerous; there are undoubtedly many overgrown sites. This once-flourishing industry has declined drastically in the past several years, and in recent times only one company has been producing grindstones. This last company has now ceased operation, and grindstone production in Washington County has become history. Composition abrasives have largely replaced naturally occurring sandstone in the grindstone industry, although sandstone is still preferred for some uses. Martin (1949) reported:

Approximately 50 per cent of the grindstones sold by the Hall Grindstone Company of Constitution, Ohio, are used in the manufacturing of handsaws and bandsaws, 25 per cent for grinding axes, and 25 per cent in the file and cutlery industries.

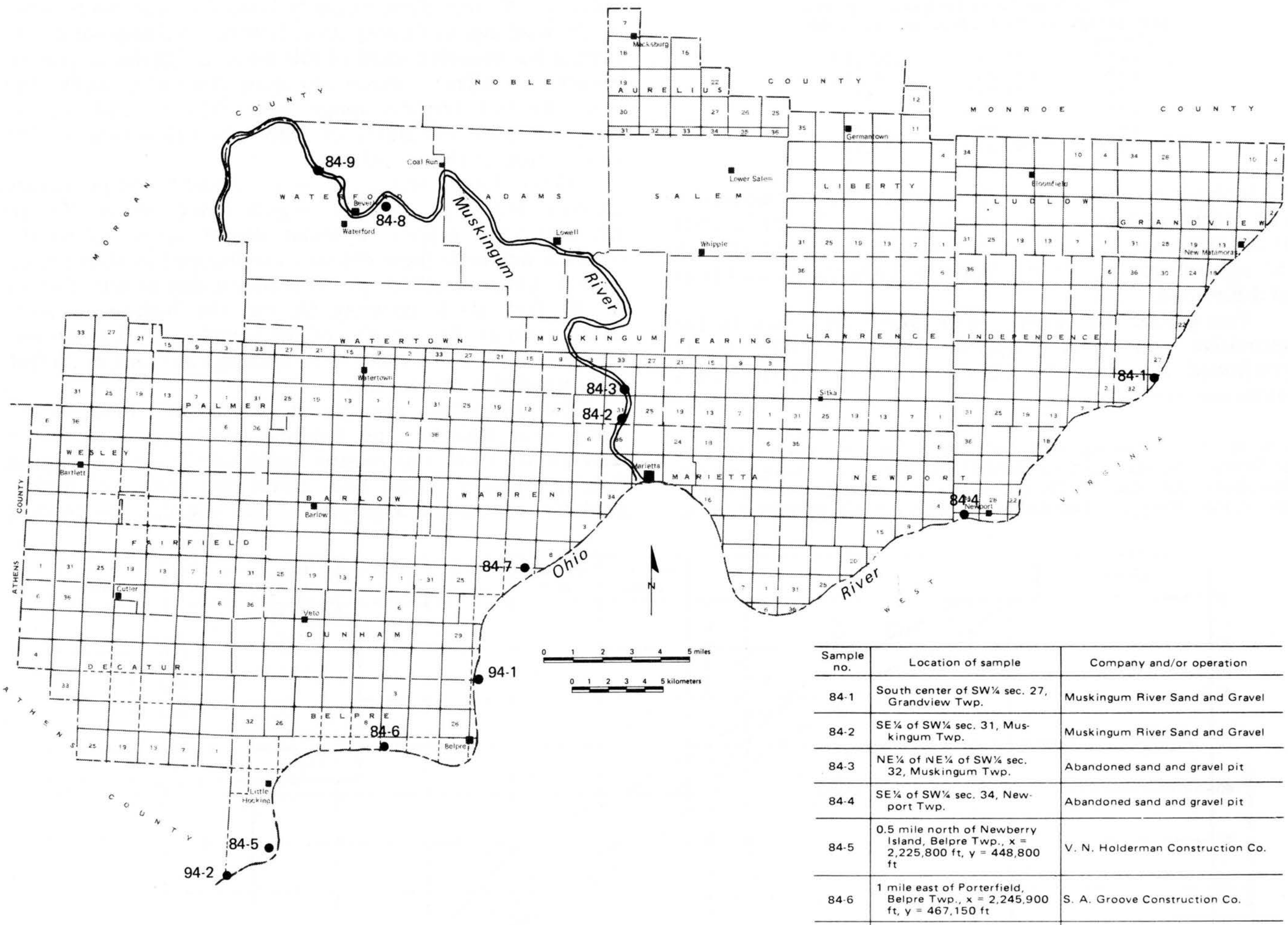
Martin (1949) cited the following characteristics as being desirable in a sandstone used for grindstones:

In order for a sandstone to be suitable as grindstone material, it must be homogeneous. It should be cemented sufficiently to hold the quartz grains together firmly, but not enough to fill the pores. A non-porous stone, or a stone in which the binding material is not removed by the coolant liquid, will tend to wear smooth under use and lose its abrasive power. If the matrix is partially removed by the coolant liquid, the quartz grains will, after a time, be plucked out by friction. This will continually present fresh sharp grains to act on the material being ground. If the stone is too friable it wears away rapidly, and the grinding done is coarse and uneven; a sharp edge or polish is unobtainable. The quartz grains should be uniform in size and angular to sub-angular.

The vertical distance between major bedding planes should be sufficient to permit the removal of a circular block three feet in thickness. The distance between the bedding planes should also be uniform. The sandstone should contain a minimum of coarse cross laminations.

Units in the relative positions of the Upper and Lower Marietta and Hundred sandstones have been the most widely quarried for grindstones; however, suitable sandstones in the sequence from the Sewickley to the Jollytown(?) have been quarried also.

Although there has been no production in recent years, locally cut sandstone was formerly used rather extensively




| Sample no. | Location of sample | Company and/or operation |
|---|---|---|
| 84-1 | South center of SW¼ sec. 27, Grandview Twp. | Muskingum River Sand and Gravel |
| 84-2 | SE¼ of SW¼ sec. 31, Muskingum Twp. | Muskingum River Sand and Gravel |
| 84-3 | NE¼ of NE¼ of SW¼ sec. 32, Muskingum Twp. | Abandoned sand and gravel pit |
| 84-4 | SE¼ of SW¼ sec. 34, Newport Twp. | Abandoned sand and gravel pit |
| 84-5 | 0.5 mile north of Newberry Island, Belpre Twp., x = 2,225,800 ft, y = 448,800 ft | V. N. Holderman Construction Co. |
| 84-6 | 1 mile east of Porterfield, Belpre Twp., x = 2,245,900 ft, y = 467,150 ft | S. A. Groove Construction Co. |
| 84-7 | SW¼ of NW¼ of NW¼ sec. 13, Warren Twp. | Trout Sand and Gravel Co. |
| 84-8 | 0.4 mile south of Dana Island, between Muskingum River and B&O RR, Waterford Twp., x = 2,250,500 ft, y = 564,600 ft | Fred Price Construction Co. |
| 84-9 | Intersection of Rtes. 76 and 70, Waterford Twp., x = 2,238,700 ft, y = 571,600 ft | Abandoned sand and gravel pit |
| 94-1 | Head of Neal Island | Ohio River Sand and Gravel Co. |
| 94-2 | Head of Mustapha Island | Kanawha Sand Co. |

FIGURE 40.—Map showing sand and gravel sample localities in Washington County, Ohio.

TABLE 18.—*Sand and gravel production for Washington County, Ohio, from 1958 to 1968*[1]

| Year | Sand (tons) | Gravel (tons) |
|---|---|---|
| 1968 | 87,086 | 371,894 |
| 1967 | 120,913 | 314,142 |
| 1966 | 123,449 | 257,277 |
| 1965 | 153,337 | 306,549 |
| 1964 | 84,414 | 198,335 |
| 1963 | 113,751 | 241,108 |
| 1962 | 84,352 | 411,447 |
| 1961 | 78,157 | 200,498 |
| 1960 | 70,694 | 288,040 |
| 1959 | 62,941 | 92,537 |
| 1958 | 65,688 | 136,934 |

[1] Data from Ohio Division of Mines, annual reports. Production data for 1969-1974 are:

| | | |
|---|---|---|
| 1969 | 77,722 | 272,555 |
| 1970 | 116,041 | 239,225 |
| 1971 | 71,757 | 289,544 |
| 1972 | 106,274 | 279,510 |
| 1973 | 152,497 | 298,662 |
| 1974 | 99,823 | 258,149 |

for bridge piers and abutments. The Hockingport sandstone was widely used for this purpose, and many old trestles built of this stone are still standing between Dunbar and Cutler on the right-of-way of the old Marietta, Columbus, and Cleveland Railroad.

Fine-grained sandstones were also used formerly for decorative and other purposes. Hildreth (1826, p. 4) mentioned many of the early uses to which the area's sandstones were put:

The rocks of Washington County are generally coarse and fine sandstone. The finer sort are used for finishing and ornamenting our fire-places; for window-sills and caps; and for monuments in our grave-yards. They are susceptible to a finish nearly or quite equal to marble. The coarser kind are used for the walls of houses, for underpinnings to brick buildings, for cellars, and for wells.

The economic potential for sandstone production in the county can only be rated as low. Manmade materials have supplanted the local sandstones for all major uses. It is possible that some amounts of native sandstones may be quarried for building trim and similar uses, but production costs would probably severely restrict such applications.

## SAND AND GRAVEL

Sand and gravel of glacial outwash origin are present in the valleys of both the Ohio and Muskingum Rivers. This material was carried by the rivers from the Wisconsinan ice front far to the north and northwest. Sand and gravel on the order of 140 feet thick formerly filled the Ohio River valley in the Washington County area; however, subsequent downcutting has removed most of this material, leaving a series of terraces at different elevations along the valley walls. The more defined terraces range from 620 to 680 feet in elevation. Sand and gravel are found also below river level to an elevation of about 540 feet.

Areas of sand and gravel are restricted to the previously glacially fed Ohio and Muskingum River valleys. Recent alluvium to a greater or lesser degree covers all of the outwash deposits; these deposits are mapped as alluvium on plate 1. Carlston (1962, p. 19) reported clay or silty clay 20 to 30 feet thick covering all but the highest terraces. Overburden at the majority of the sample sites (fig. 40) was generally only a few feet thick, although as much as 20 feet was recorded at one locality.

The industrial development of the Ohio River valley, along with highway and building construction, creates a large demand for construction aggregates in the Washington County vicinity. Sand and gravel are the only readily available sources of aggregate in the region. The greatest

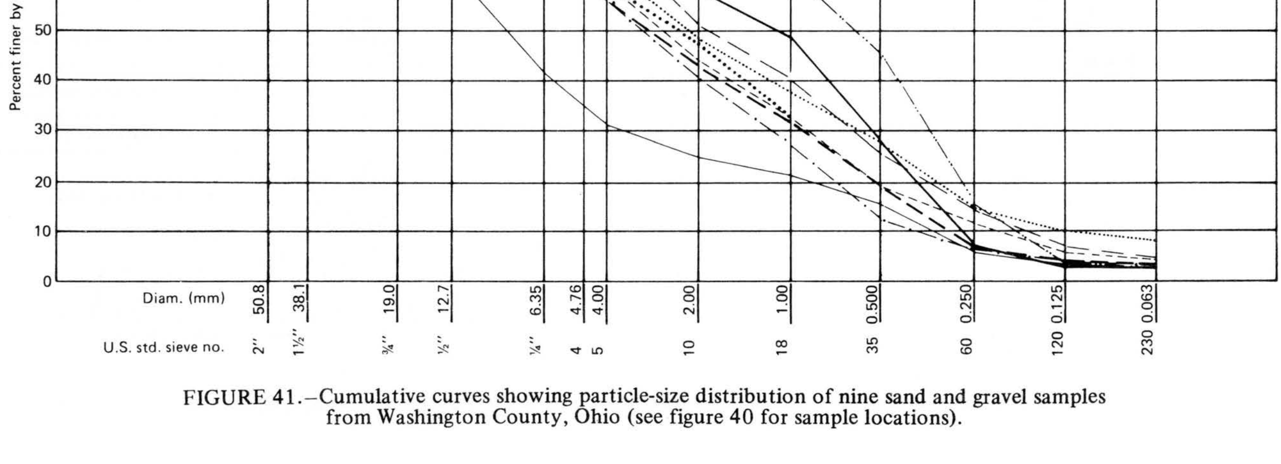



FIGURE 41.—Cumulative curves showing particle-size distribution of nine sand and gravel samples from Washington County, Ohio (see figure 40 for sample locations).

TABLE 19.–*Size analyses of 11 sand and gravel samples*[1] *from Washington County, Ohio*

| Particle size (diameter in mm) | Percent remaining on or above smallest screen in particle size range | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Ohio River samples | | | | | | | Muskingum River samples | | | |
| | 84-1 | 84-4 | 84-7 | 94-1[2] | 84-6 | 84-5 | 94-2[2] | 84-2 | 84-3 | 84-8 | 84-9 |
| Pebble (64-4) | 69.6 | 38.5 | 33.3 | 58.3 | 18.3 | 44.1 | 71.1 | 31.3 | 41.6 | 44.3 | 40.7 |
| Very fine pebble (4-2) | 5.9 | 14.5 | 10.2 | 15.9 | 10.4 | 15.1 | 2.8 | 17.6 | 14.9 | 13.4 | 12.3 |
| Very coarse sand (2-1) | 3.1 | 9.8 | 8.5 | 7.3 | 9.0 | 13.5 | 3.2 | 10.9 | 11.4 | 10.7 | 14.2 |
| Coarse sand (1-0.5) | 6.2 | 10.7 | 20.3 | 9.1 | 17.2 | 14.7 | 11.2 | 14.6 | 13.6 | 13.1 | 16.1 |
| Medium sand (0.5-0.25) | 9.4 | 13.3 | 21.8 | 6.1 | 29.8 | 6.3 | 9.6 | 11.1 | 7.5 | 12.2 | 12.3 |
| Fine sand (0.25-0.125) | 2.7 | 4.1 | 3.2 | 1.3 | 11.2 | 2.0 | 1.6 | 7.5 | 5.4 | 2.7 | 3.4 |
| Very fine sand (0.125-0.063) | 0.7 | 1.6 | 0.4 | 0.4 | 1.3 | 1.0 | 0.2 | 1.7 | 1.1 | 0.7 | 0.7 |
| Silt and clay (<0.063) | 2.4 | 7.5 | 2.3 | 1.6 | 2.8 | 3.3 | 0.3 | 5.3 | 4.5 | 2.9 | 0.3 |

[1] See figure 40 for localities.
[2] Samples collected from dredges operating in the Ohio River. Finer particle sizes partially washed out by dredging process. Degree of representation in finer size ranges uncertain.

portion of the sand and gravel tonnage produced each year in Washington County is used for building and paving purposes; production naturally increases during periods of heavy building and particularly during highway construction. Sand and gravel production for the period 1958-1968 is shown by table 18.

Although common sand and gravel are plentiful, a very large percentage of the available reserve acreage is being utilized for building sites and truck farming. The most significant terrace areas on the Ohio River are (1) south of New Matamoras, (2) the vicinity of Newport, (3) southeast of Reno, (4) the vicinity of Gravelbank, from Belpre west to Porterfield (formerly Center Belpre), and southernmost Belpre Township opposite Newberry Island. In the Muskingum River valley the wide river bottoms in the vicinity of Beverly, Coal Run, and Lowell, and from Dam No. 2 south to Marietta constitute the largest areas of sand and gravel. The abandoned Ohio River channel in the Newport vicinity and a similar channel of the Muskingum at Coal Run would seem to offer considerable potential for sand and gravel reserves.

Representative samples collected from both the Ohio and Muskingum Rivers (fig. 41) show that the outwash materials found in this area are quite coarse. Screen analyses of 11 representative samples (table 19) show that an average of approximately 45 percent of these materials falls into the pebble size classification. Pebble counts (table 20) of 100 specimens from each sample indicate that from 44 to 71 percent of this fraction is derived locally, and the remainder is of "foreign" origin. The materials considered foreign to this region include quartz, quartzite, chert, and igneous rocks. Minor amounts of chert could be derived locally, but chert is rare in the surrounding Pennsylvanian and Permian rocks; for these outwash deposits an outside source is indicated. With the exception of sample 84-2, the samples collected from the Muskingum River show relatively higher

TABLE 20.–*Rock types from 11 Washington County, Ohio, sand and gravel samples*[1] *as determined by pebble counts*

| Lithology | Percent of total | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Ohio River samples | | | | | | | Muskingum River samples | | | |
| | 84-1 | 84-4 | 84-7 | 94-1 | 84-6 | 84-5 | 94-2 | 84-2 | 84-3 | 84-8 | 84-9 |
| Quartz | 2 | 0 | 7 | 13 | 15 | 14 | 10 | 10 | 10 | 12 | 3 |
| Quartzite | 5 | 3 | 5 | 2 | 2 | 4 | 8 | 8 | 6 | 2 | 3 |
| Chert | 29 | 24 | 20 | 22 | 12 | 21 | 24 | 22 | 9 | 16 | 12 |
| Igneous rock | 10 | 10 | 14 | 18 | 15 | 17 | 12 | 11 | 4 | 11 | 13 |
| Limestone | 2 | 0 | 14 | 9 | 10 | 4 | 0 | 4 | 19 | 16 | 22 |
| Shale | 0 | 2 | 0 | 1 | 2 | 1 | 1 | 1 | 0 | 1 | 1 |
| Sandstone | 34 | 34 | 25 | 26 | 31 | 22 | 26 | 27 | 29 | 23 | 26 |
| Siltstone | 18 | 27 | 15 | 8 | 13 | 17 | 19 | 17 | 23 | 19 | 20 |

[1] See figure 40 for localities.

percentages of limestone and lower percentages of chert (table 20) than do those from the Ohio River. The Muskingum River samples also tended to have slightly lower percentages of igneous rock types.

Most of the igneous rocks are granitic, with gneissic materials being second in abundance; only a very small percentage of the igneous pebbles can be assigned to the mafic rock types. The local contribution includes limestone, shale, sandstone, siltstone, and trace amounts of coal. The sandstones are largely very fine grained; in many cases there is difficulty in separating siltstones from sandstones. Because of relative ease of disintegration, shale and coal comprise only a very small part of the gravels in this area. Some increase in these components might be expected in the finer size fractions.

Cumulative curves were plotted (fig. 41) for nine samples to determine if there were significant differences in particle-size distribution between the Ohio River and Muskingum River samples. Two samples having some degree of uncertainty regarding accuracy of representation were omitted from this chart (see footnote 2, table 19). Figure 41 shows no substantial or systematic particle-size changes between the Muskingum or Ohio Rivers or between the various sample sites on the individual streams. These data and those of table 19 indicate deposition of similar materials under essentially similar conditions in both drainage systems.

TABLE 21.—*Size analyses of alluvial materials deposited in the valleys of the Teays-age Barlow Creek system*[1]

| Sample number | Sand | Silt | Clay | Remarks |
|---|---|---|---|---|
| 84-0457 | 9 | 63 | 28 | |
| 84-0458 | 33 | 41 | 26 | |
| 84-0459B | 20 | 50 | 30 | |
| 84-0468 | 8 | 56 | 36 | |
| 84-0580 | 0 | 21 | 79 | Highly laminated |
| 84-0600B | 14 | 56 | 30 | |
| 84-0625 | 0 | 43 | 57 | Laminated |

[1] See pages 84-86, 92, 102, 103, 106 for sample location descriptions, evaluation of ceramic potential, and other data.

## MOLDING SAND

Phillips and others (1926, p. 20, 23) reported that molding sand was formerly mined in the vicinity of both Barlow and Vincent from soils described as Holston (high-terrace phase) and Vincent silt loams. Areas of molding sand production identified by these authors as Holston silt loam (high-terrace phase) are included along with the Vincent silt loam and are shown on plate 1.

Soils mapped in western Washington County as Vincent silt loam and contiguous Holston silt loam compose a complex sequence of fluvial and lacustrine sediments deposited in the abandoned valleys and adjacent areas of the drainage system of the Teays-age Barlow Creek and are correlative with the Minford silts of Stout and Schaaf (1931).

Materials associated with these deposits range from sand to laminated clay (table 21). Sample 84-0458 was taken in the general vicinity of the area where molding sand production has been reported. This sample compares favorably with those collected near other reported molding sand localities. Although the areal extent of these deposits is substantial, irregularities in thickness and character detract from their potential as a mineral resource.

## WATER

Water is one of our most important natural resources, and its relative availability is a definite aspect of the economic potential of almost every area. The Ohio and Muskingum Rivers are the greatest sources of surface water in the county, and industrial water supplies could be obtained from these two rivers at almost any point along their courses. Water could also be obtained in sufficient quantities for industry by impoundments on the larger tributaries of these rivers. The availability of ground water in Washington County is described briefly in a series of reports by Walker (1958, 1962a, b) and by Schmidt (1959). The following remarks are summarized from these reports.

Large volumes of ground water are restricted to the valleys of the Ohio and lower Muskingum Rivers, where as much as 1,000 gallons per minute can be produced. This volume can be obtained only where the valley is filled with relatively thick layers of sand and gravel. Thinner layers of sand and gravel may yield considerable water, but cannot provide industrial supplies. Wells in most of the Muskingum River valley from shortly above Marietta to Beverly are capable of producing 100 to 500 gallons of water per minute. Above Beverly to the county line, production on the order of 25 to 100 gallons per minute is more common.

Water supplies from wells drilled in areas of the county away from the two major river valleys are very limited. Many such wells average less than 2 gallons per minute, and cisterns are quite common in these areas. Industrial water supplies obviously cannot be acquired from wells.

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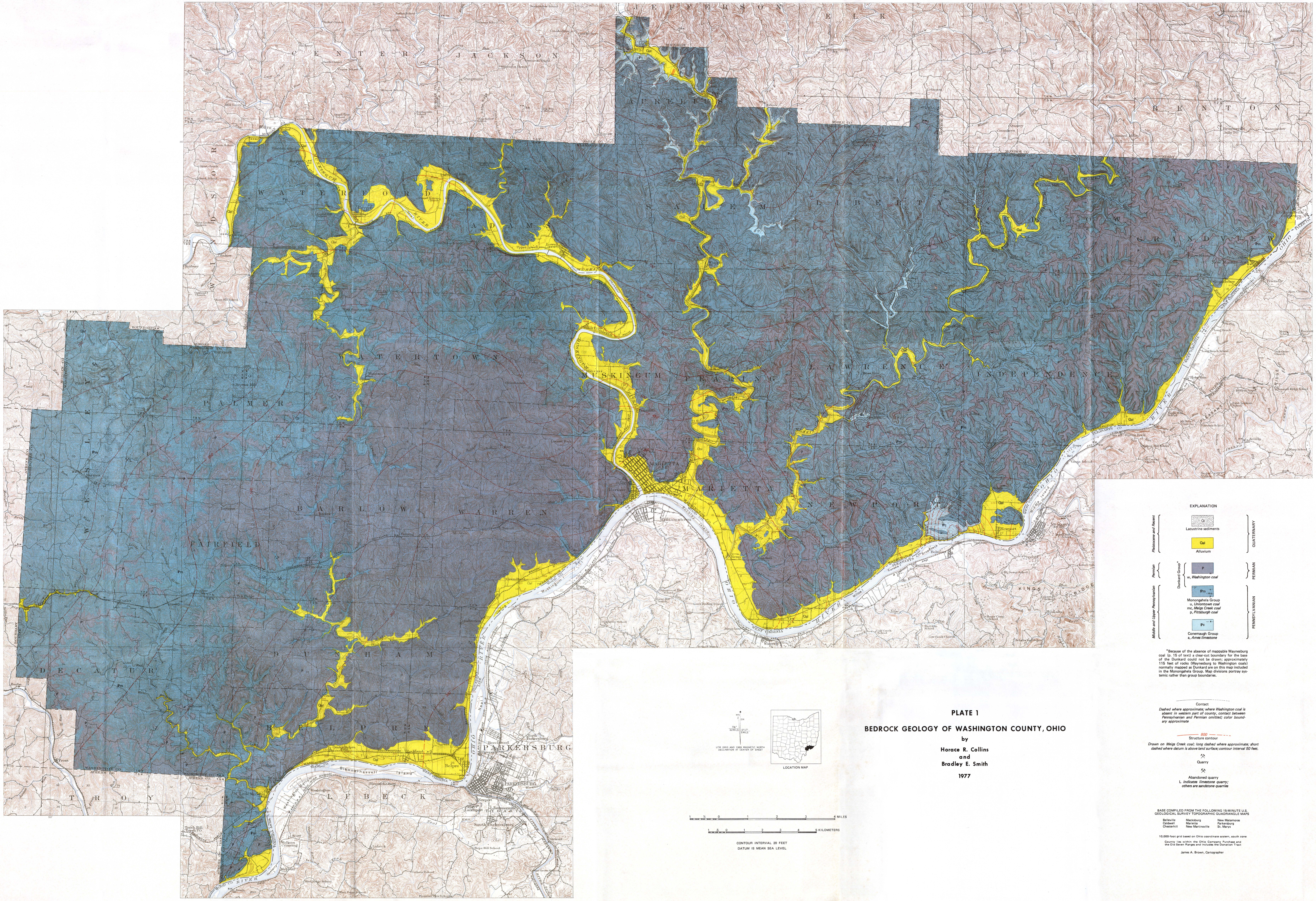
STATE OF OHIO
James A. Rhodes, Governor
DEPARTMENT OF NATURAL RESOURCES
Robert W. Teater, Director
DIVISION OF GEOLOGICAL SURVEY
Horace R. Collins, Chief





# PLATE 1

## BEDROCK GEOLOGY OF WASHINGTON COUNTY, OHIO

by

Horace R. Collins
and
Bradley E. Smith

1977

CONTOUR INTERVAL 20 FEET
DATUM IS MEAN SEA LEVEL

### EXPLANATION

QUATERNARY — Pleistocene and Recent

Ql — Lacustrine sediments

Qal — Alluvium

PERMIAN — Permian — Dunkard Group*

P — w, *Washington coal*

PENNSYLVANIAN — Middle and Upper Pennsylvanian

Pm — Monongahela Group
u, *Uniontown coal*
mc, *Meigs Creek coal*
p, *Pittsburgh coal*

Pc — Conemaugh Group
a, *Ames limestone*

*Because of the absence of mappable Waynesburg coal (p. 15 of text) a clear-cut boundary for the base of the Dunkard could not be drawn; approximately 115 feet of rocks (Waynesburg to Washington coals) normally mapped as Dunkard are on this map included in the Monongahela Group. Map divisions portray systemic rather than group boundaries.

Contact

*Dashed where approximate; where Washington coal is absent in western part of county, contact between Pennsylvanian and Permian omitted; color boundary approximate*

800

Structure contour

*Drawn on Meigs Creek coal; long dashed where approximate; short dashed where datum is above land surface; contour interval 50 feet.*

Quarry

Abandoned quarry
L *indicates limestone quarry; others are sandstone quarries*

BASE COMPILED FROM THE FOLLOWING 15-MINUTE U.S. GEOLOGICAL SURVEY TOPOGRAPHIC QUADRANGLE MAPS

| | | |
|---|---|---|
| Belleville | Macksburg | New Matamoras |
| Caldwell | Marietta | Parkersburg |
| Chesterhill | New Martinsville | St. Marys |

10,000-foot grid based on Ohio coordinate system, south zone

County lies within the Ohio Company Purchase and the Old Seven Ranges and includes the Donation Tract

James A. Brown, Cartographer

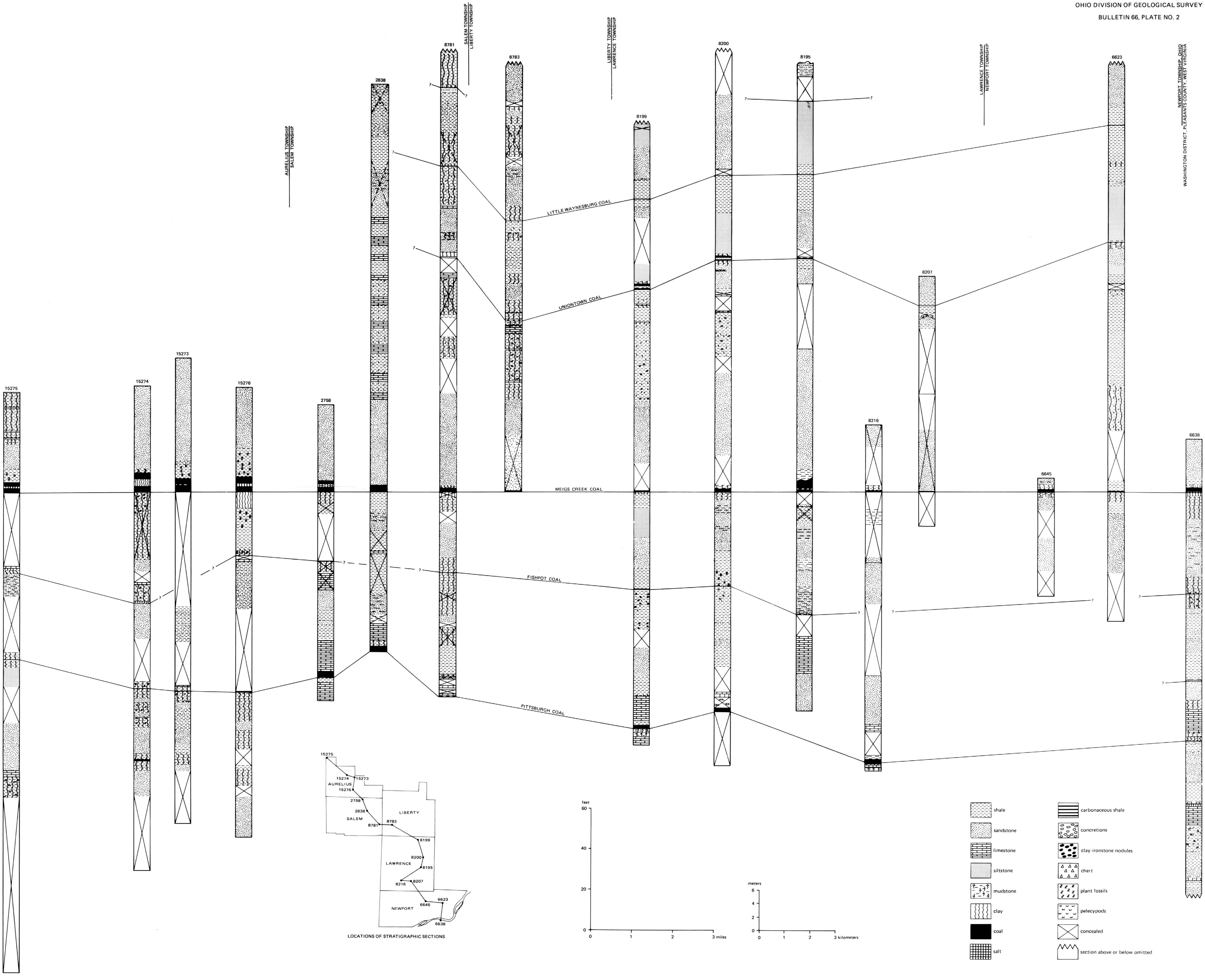



**Plate 2 Columnar sections showing the stratigraphic relation of the Meigs Creek coal and adjacent beds**

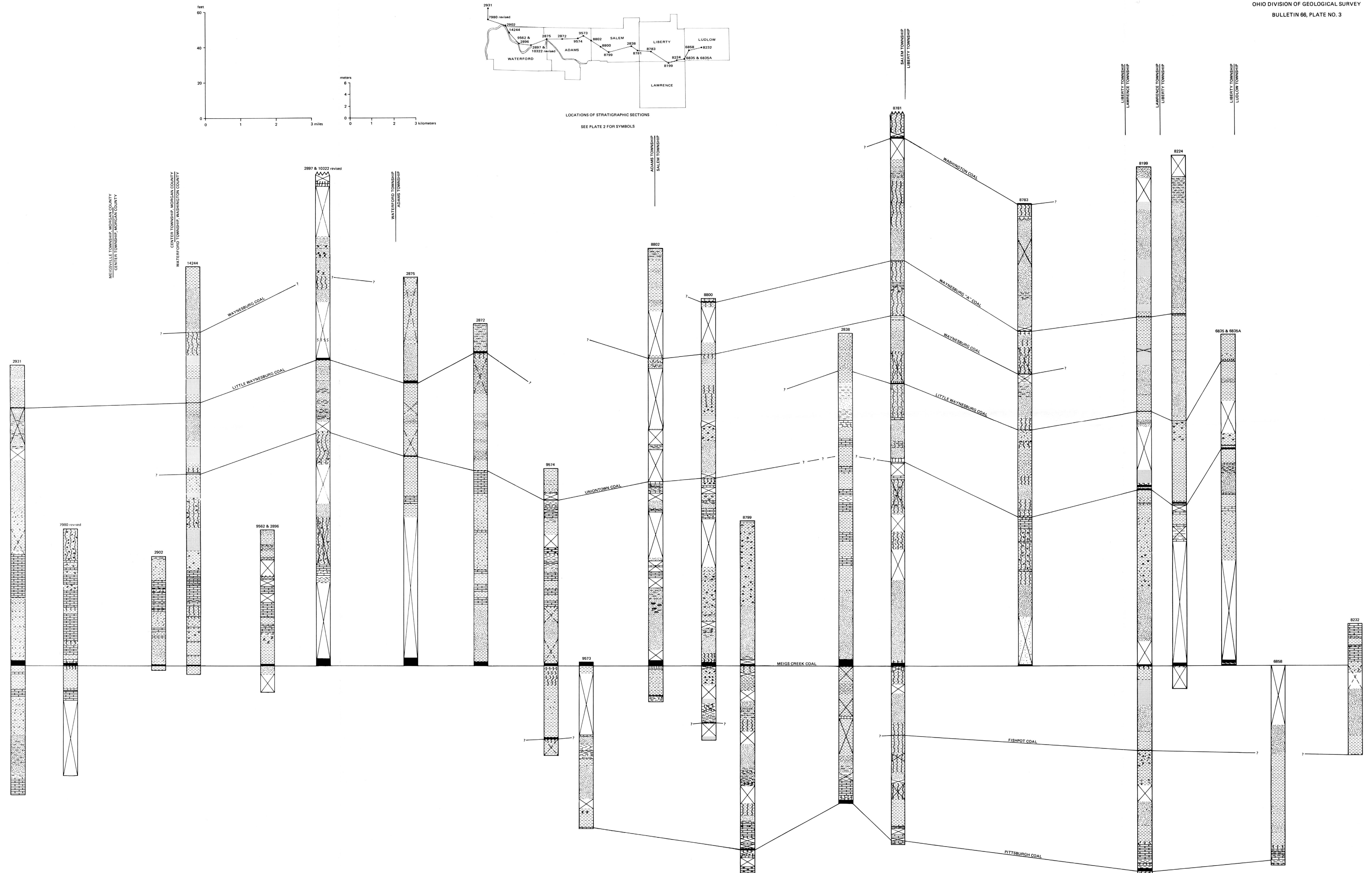



**Plate 3 Columnar sections showing the stratigraphic relation of the Meigs Creek coal and adjacent beds**


Plate 4 Columnar sections showing the stratigraphic relation of the Uniontown coal and adjacent beds

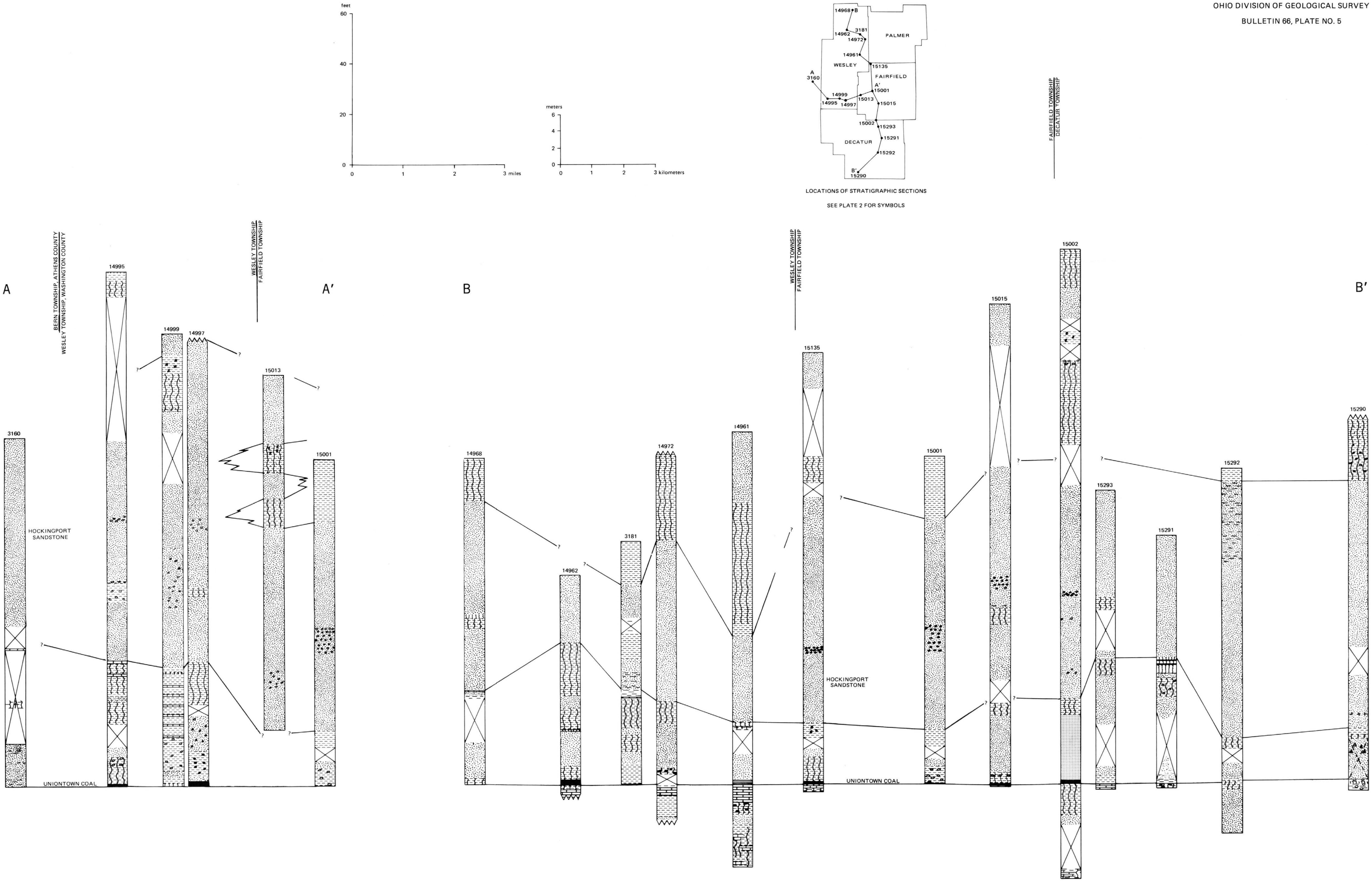



**Plate 5 Columnar sections showing the stratigraphic relation of the Hockingport (Waynesburg) sandstone and adjacent beds**

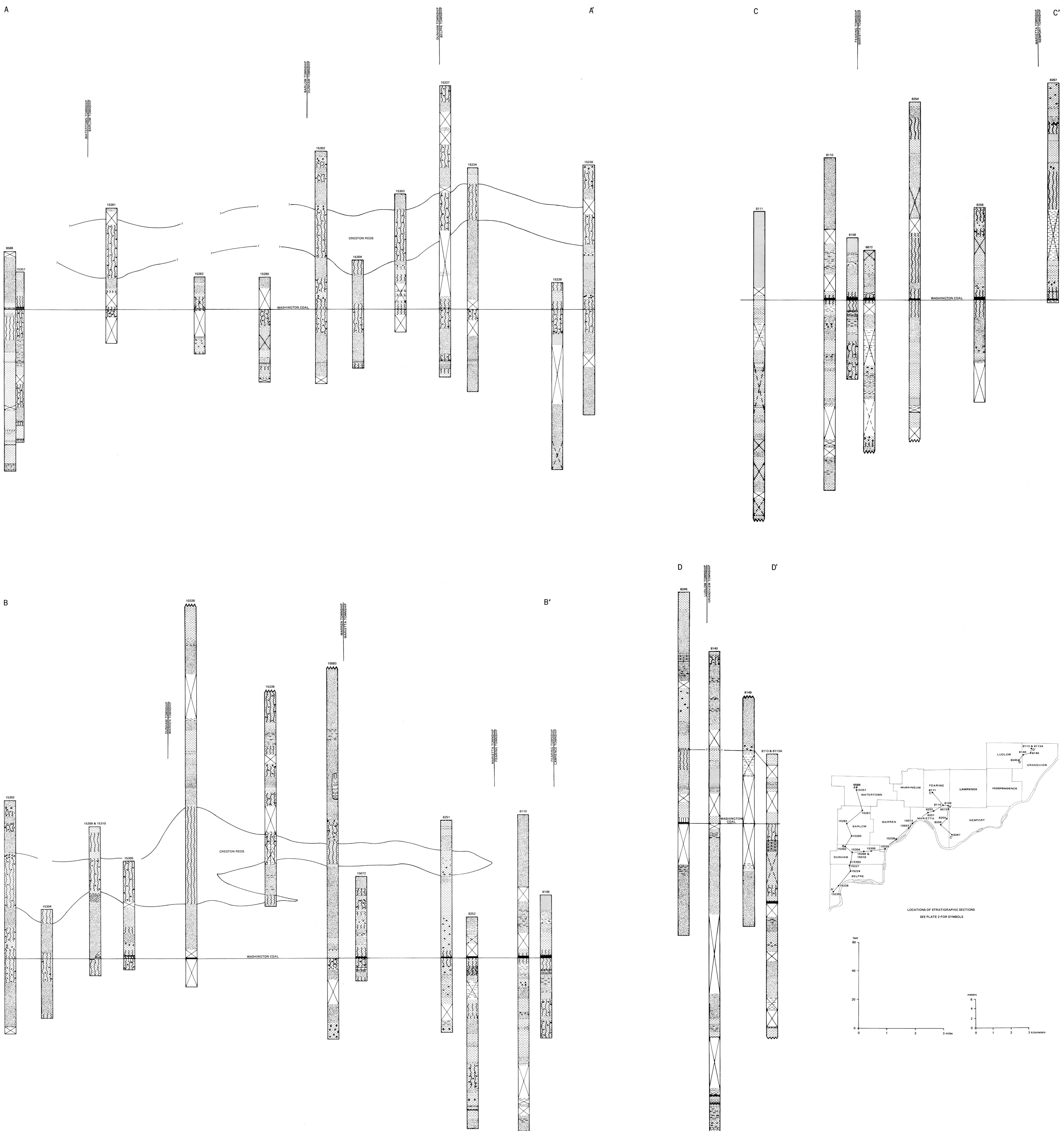



Plate 6 Columnar sections showing the stratigraphic relation of the Washington coal and adjacent beds

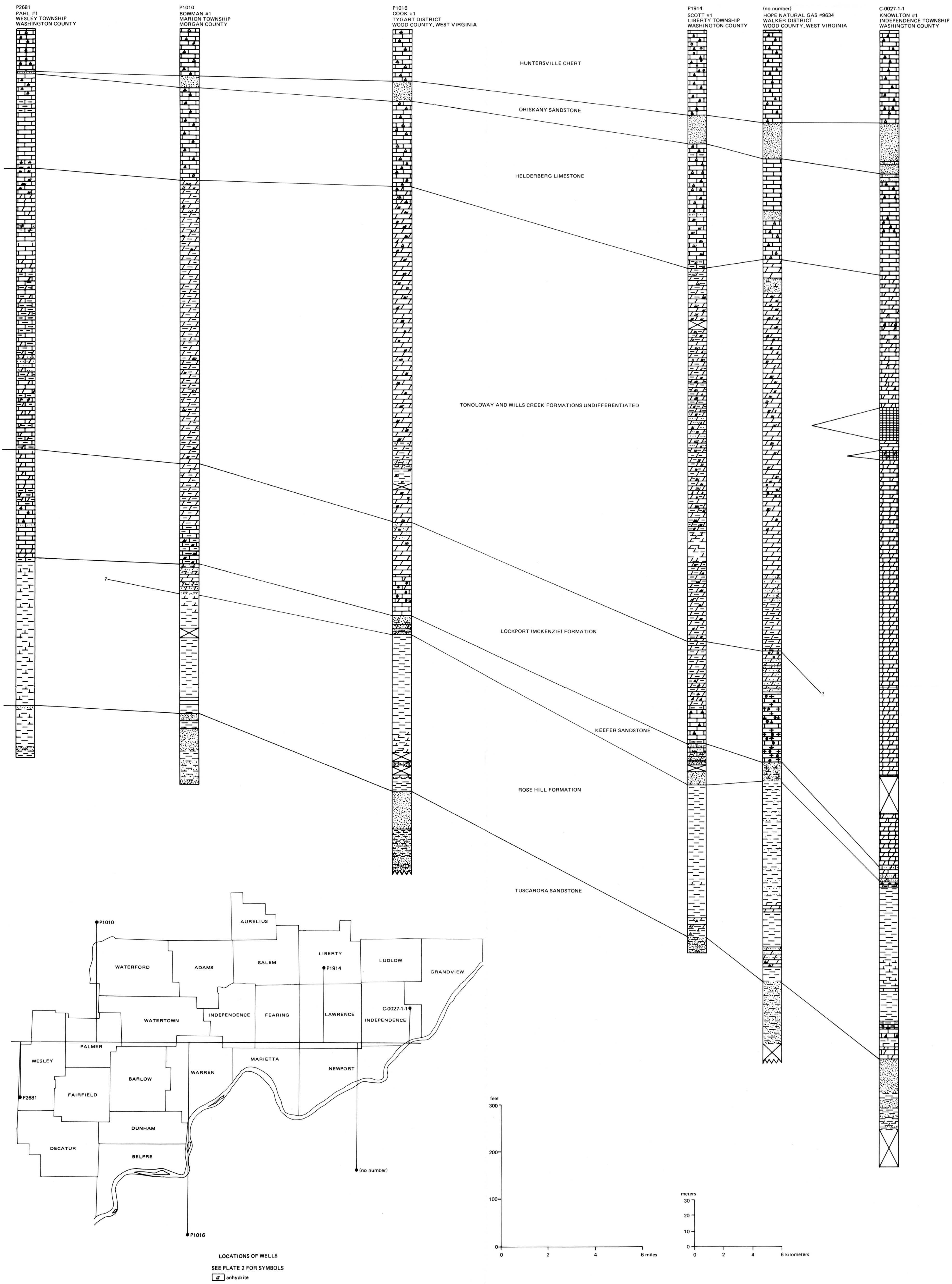



**Plate 7 Columnar sections showing the stratigraphic relation of Lower Silurian through Middle Devonian units**

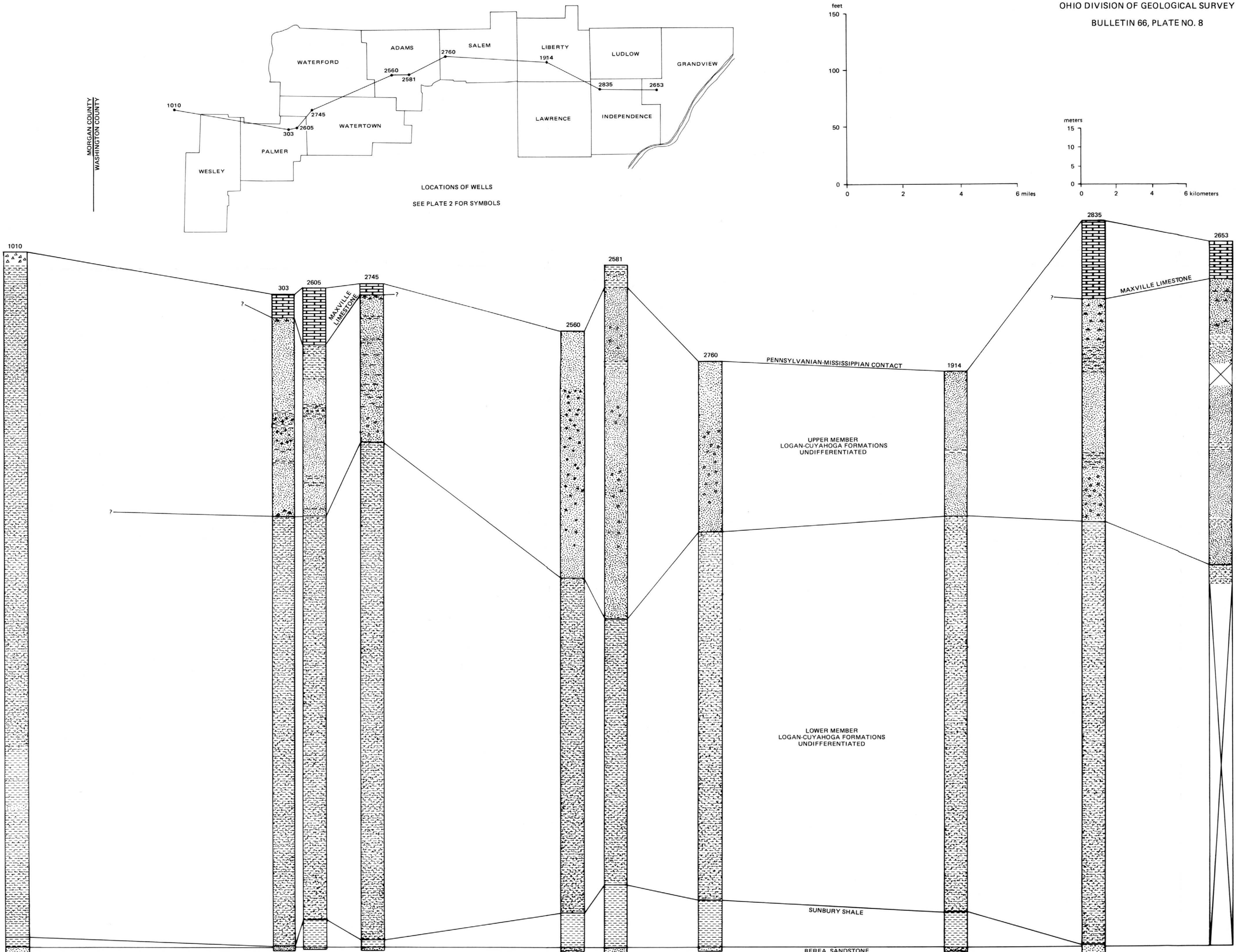
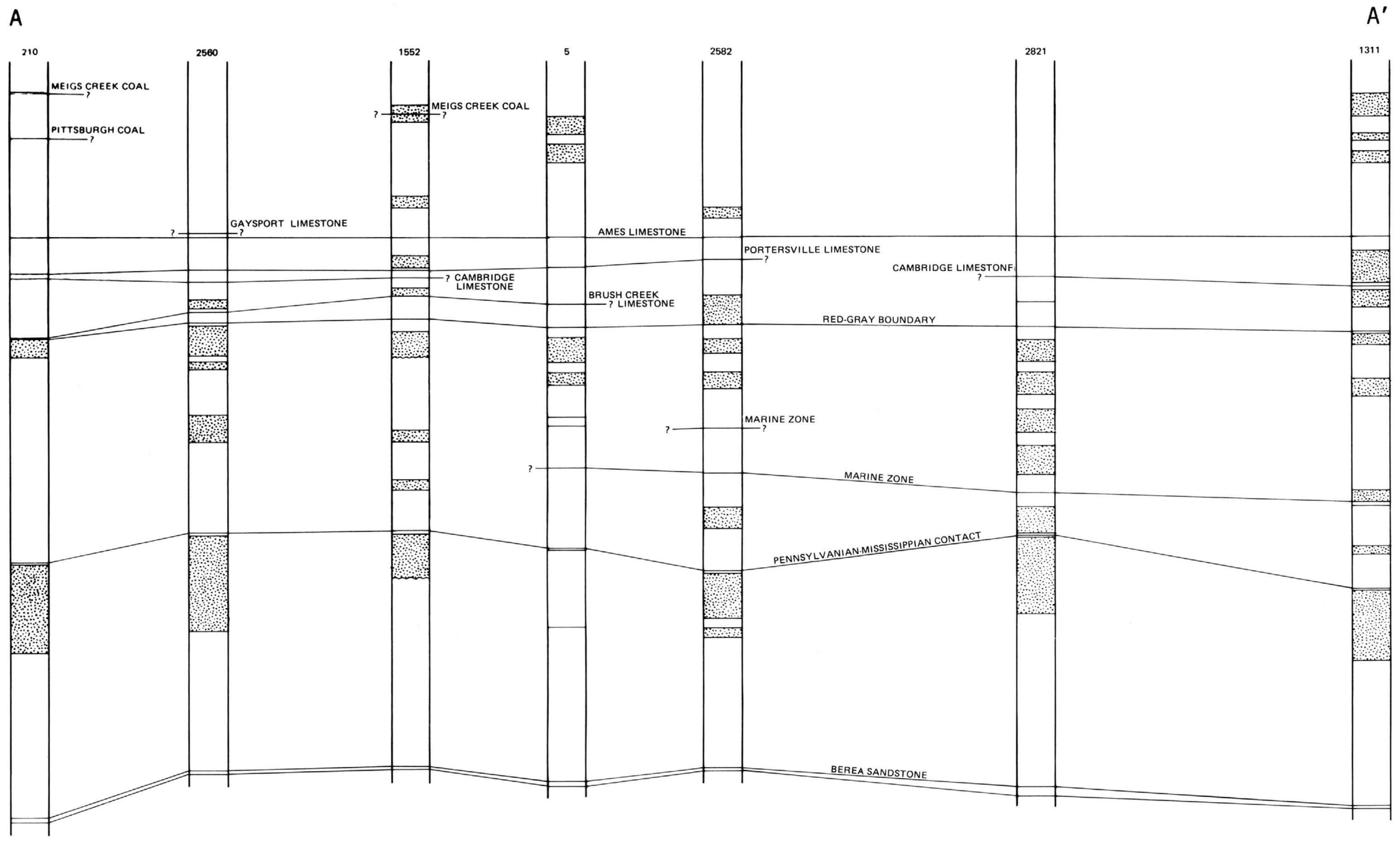
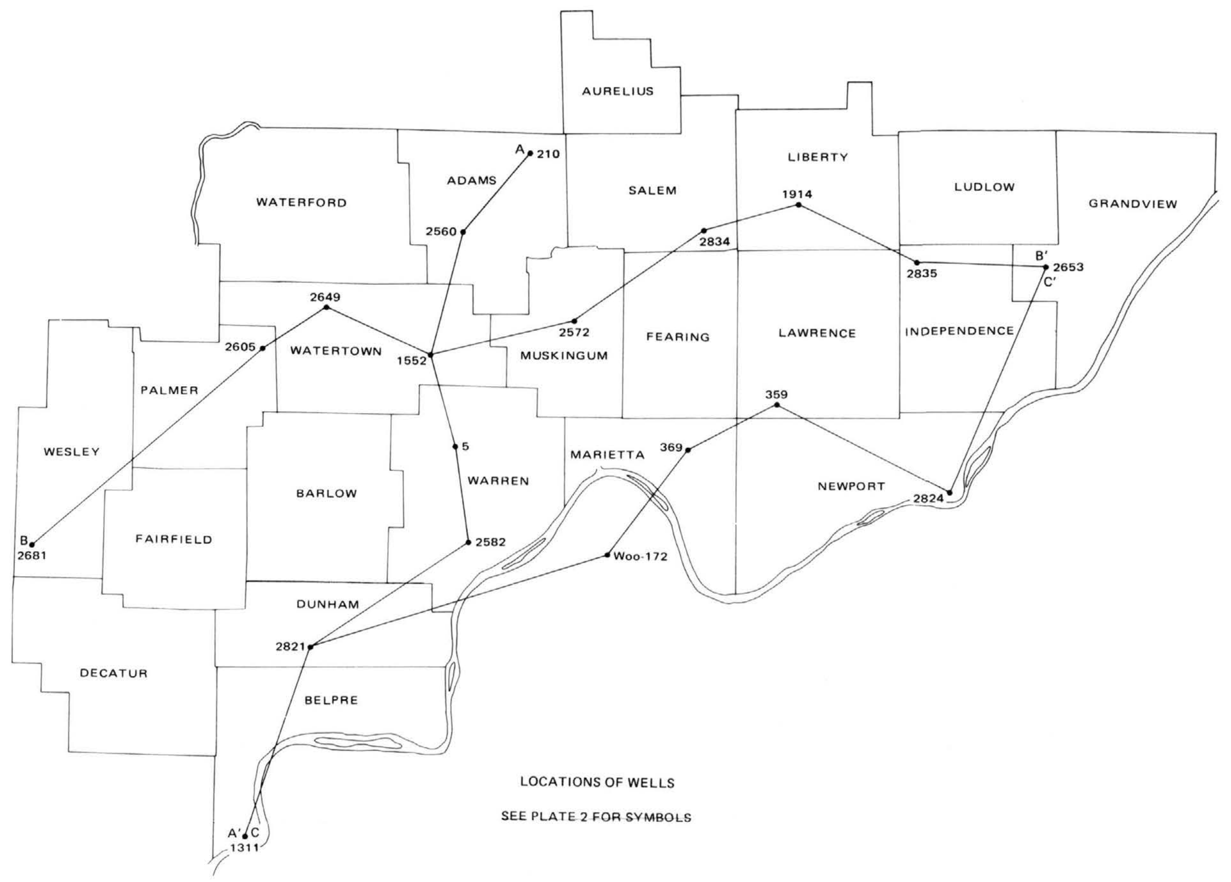
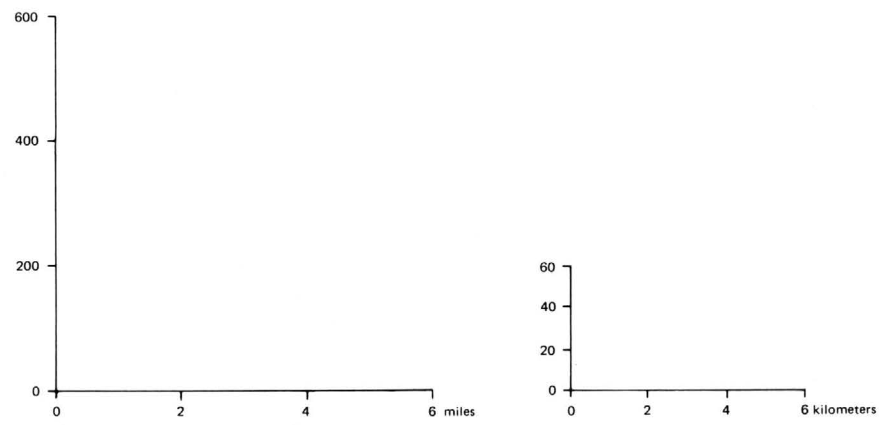
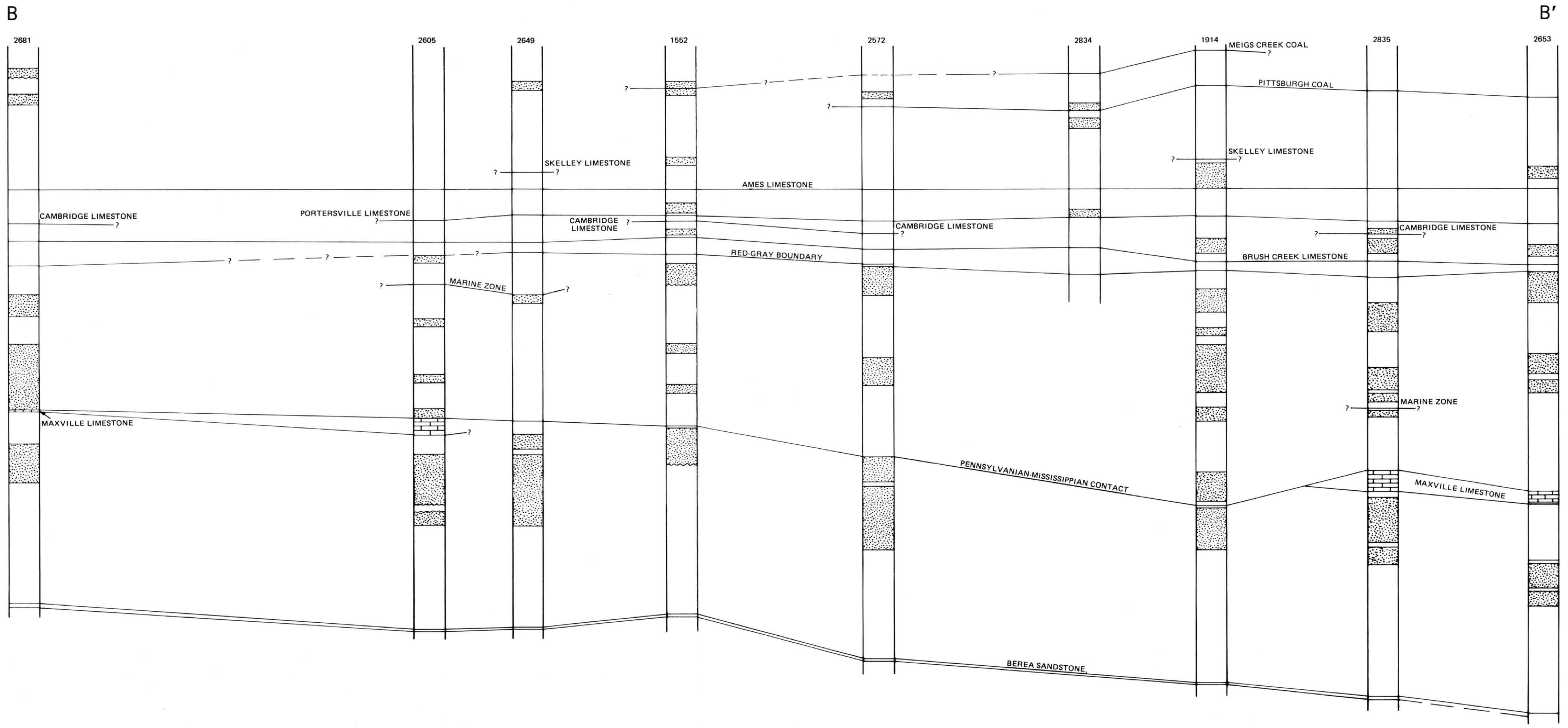



**Plate 8 Columnar sections showing the stratigraphic relation of Mississippian units**



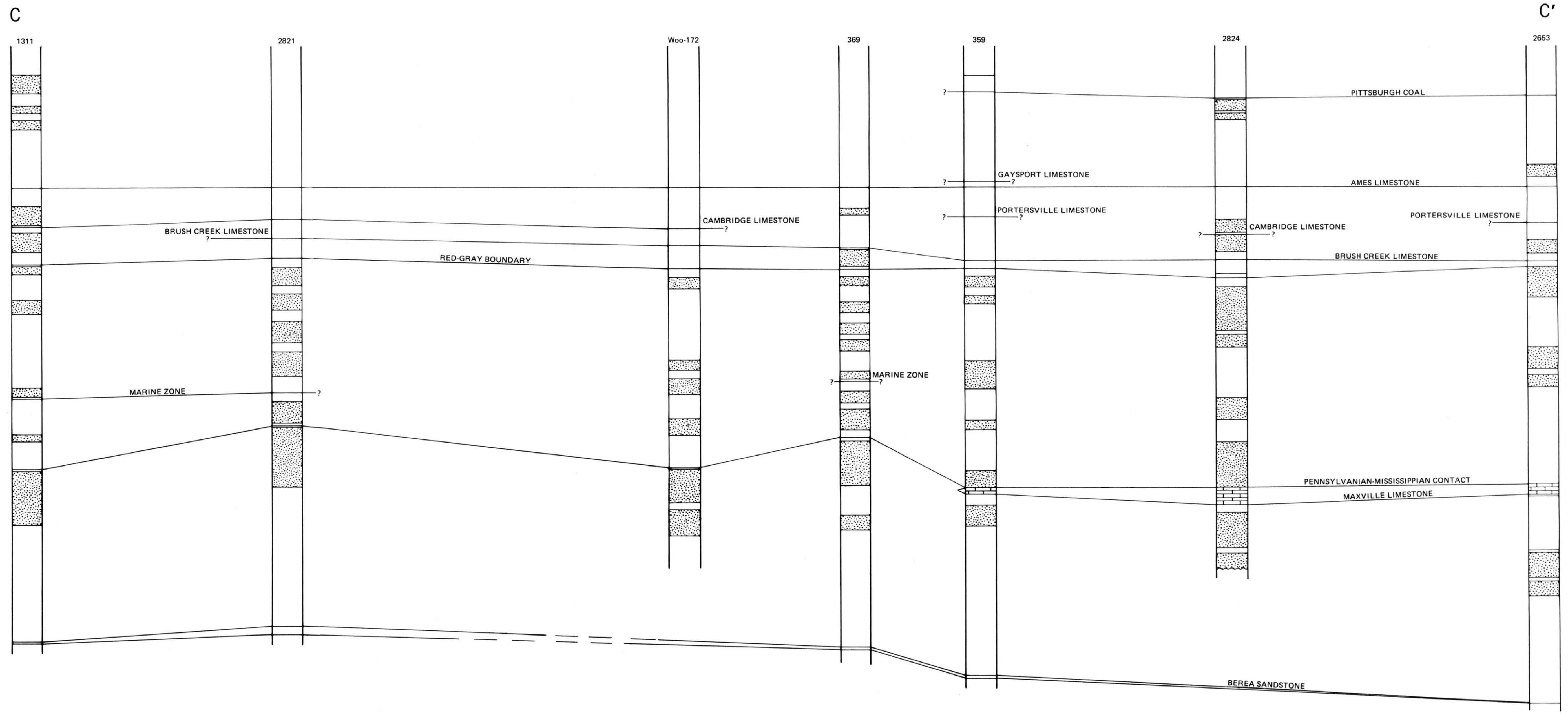




**Plate 9 Generalized columnar sections showing the stratigraphic relation of units between the Berea Sandstone and the Meigs Creek coal**

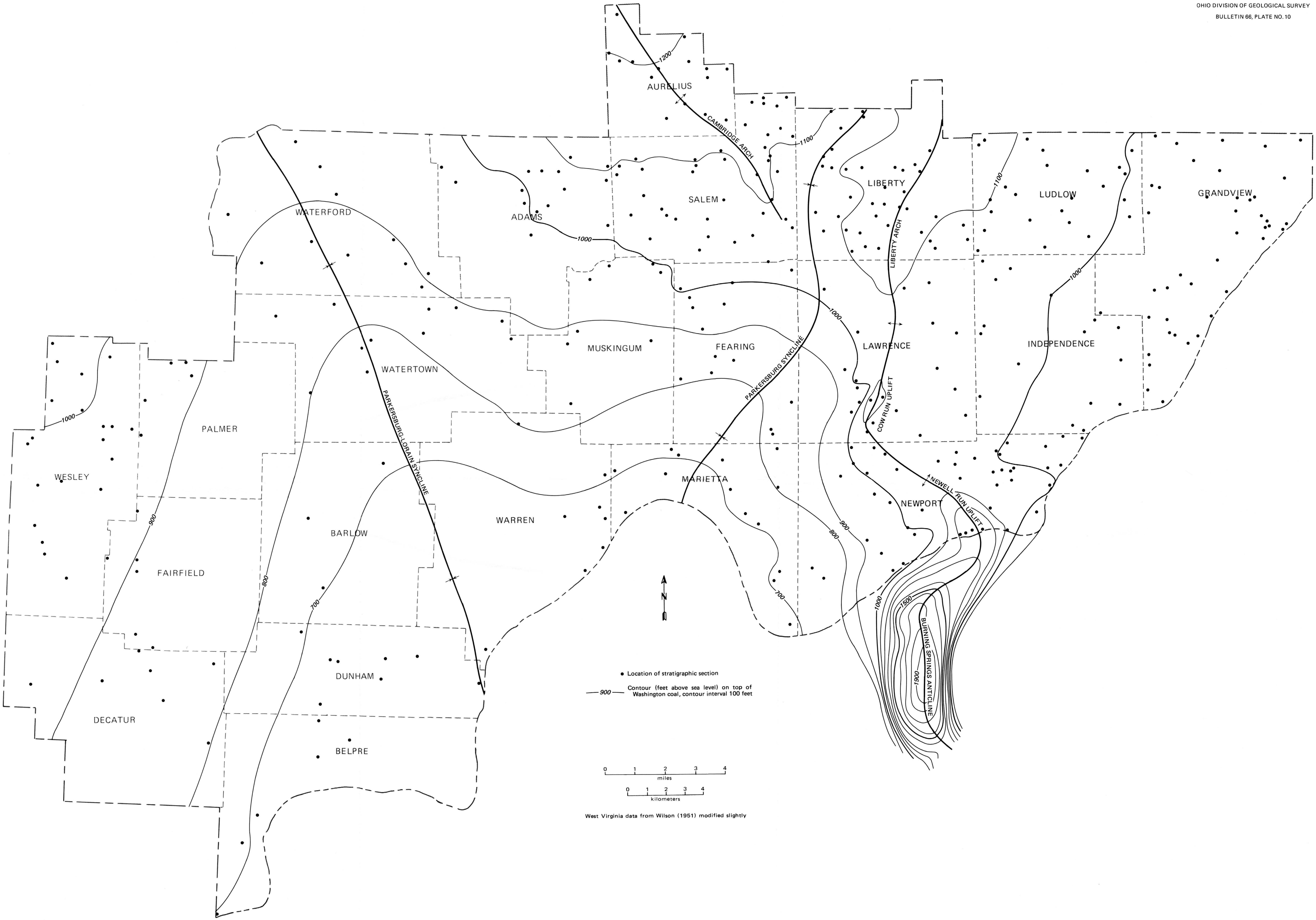



**Plate 10 Structure on top of the Washington coal**

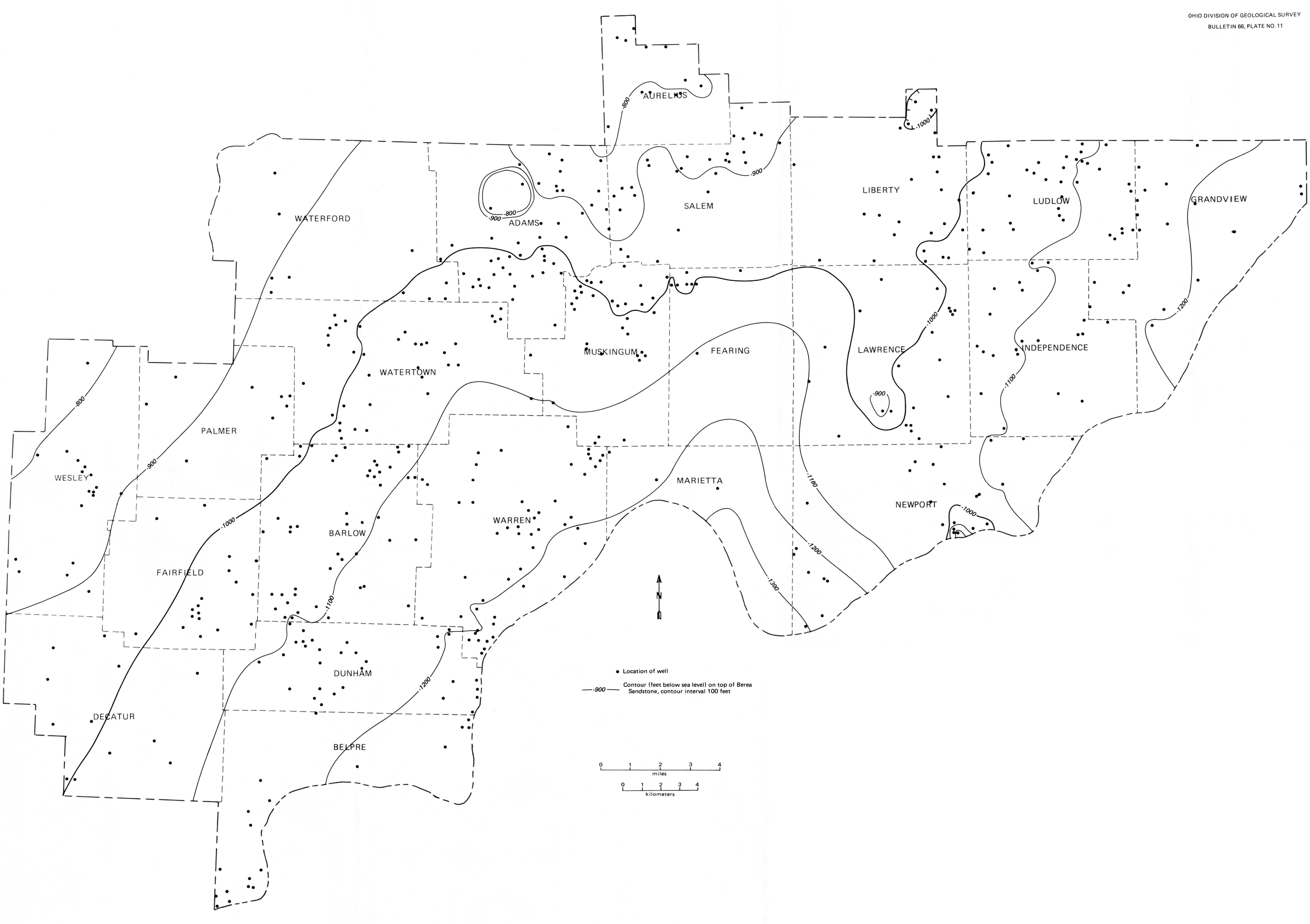



**Plate 11 Structure on top of the Berea Sandstone**